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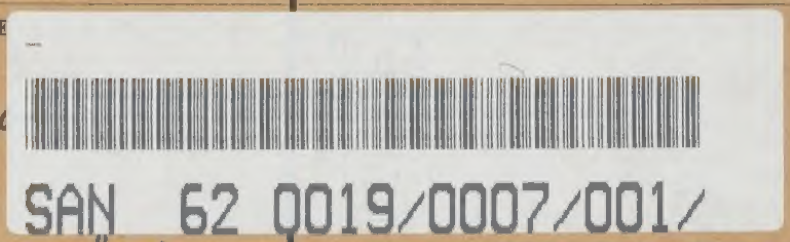

EFFECT OF ELECTRO-MAGNETIC PULSE

W 1895

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FILE NUMBER SAN 62 19/7/1

CLOSED INDEX HEADINGS CLOSED

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SECRET

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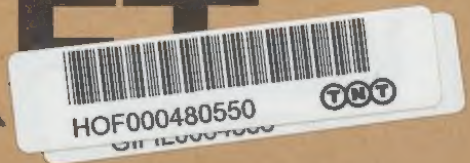

32628—6-9-73 XBD 1713

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ENTIFIC ADVISERS' BRANCH

HOME OFFICE

SAN

62

19/7/1

CLOSED

COMMUNICATIONS

RELATED PAPERS

19/1/1

N 19/2/1 SAG 10/62/1

EFFECT OF ELECTRO-MAGNETIC PULSE

Survived Last Review 6/4/78 ER Stanbury

DESTINATION	DATE	Initials	DESTINATION	DATE	Initials	DESTINATION	DATE	Initials
Mr Lavy	5/2	GDS	Mr Sargeant	5/4/65	GDS			
Mr Stanbury	14/12/64	Fld	Registry	24/8/66	GDS.			
Mr Sargeant	29/12/64	GDS	Registry	1/4/66				
"	12/3/65		Mr Lavy	20/6	GDS			
Mr Lavy	19/3/65	GDS	Registry	17/7	FHP.			
registry	20/4	Fld	Registry	20.1.72	F.H.P.			
"	"	"						
Mr Stanbury	21/4	GDS						
Mr Sargeant	7/4	GDS						
Mr Stanbury	13.5.64	ESS						
"	4.6.	Fld						
Mr Lavy	29/7/64	GDS						
Registry	20/8	Fld						
"	24/6	-						
Mr Lavy	20/8	GDS						
Registry	22/4							
Mr Lavy.								
Registry	31/12							
"	29/12							
	5/1/65							

Please see also docs 45–67 on file SAN 19/1/1

MINUTES

(Additional Minute-sheets should be filed on this side)

See also Garrard's Confidential "Some Observations of the Electro-Magnetic Flash Damage resulting from Nuclear Explosions". (doc 6)

Doc. 1. Mr Furth asks if SAB could examine the likely effects of a nuclear burst on telephone equipment and what possible alternatives it may be necessary to arrange.

5.11.62

Mr Sargeaunt.

You may like to look at Doc 65 in the attached file SAN 19/1/1. Garrard also came and spoke on this subject at our Scientific Advisers Conference in May and the report of it is just out (Page 13). I have spoken to Garrard and he is just off to the U.S. for a meeting in Washington on 12/11 at which basic results in this general field are to be discussed. I have arranged to contact him on 16 days with a view to organising a follow-up meeting with the same group that met on 2nd/3 with possibly the addition of a G.P.O. man. I think we should be able to give a reasonable appreciation after this

E.H. Stanbury
7.11.62

Mr Furth Sargeaunt.

I have spoken with Mr Sargeaunt and he is very anxious that we should press on with this. Could you please arrange the necessary meeting with Garrard + explain to him how important it is from our point of view. I think we should try and have this before Christmas.

E.H. Stanbury
5.12.62

Mr Parry

Meeting arranged, to take place in Mr Stanbury's room at 11 a.m. on Thursday Dec. 20th. Mr Watson of Communications Branch will come, and I asked him to bring a G.P.O. man. Watson rang Parry of G.P.O., who suggested a Mr J.H.H. Merriman. I confirmed – through the H.O. Security Office – that he is P.V.'d, so I rang & arranged for him to come. E.H. Parry 14.12.'62

Mr Stanbury

Reference SAH 19/7/1
62

Meeting was held on 20th Dec. as arranged Mr Sargeaunt was present. Garrard presented us with Doc 2, Ref XY/B95/01. which was a brief summary of a symposium he had attended on 13/14th Nov 1962. to discuss some of the results of Small Boy on which some £20 megabucks had been spent. A representative of the Bell Telephone boy – one of the major contractors – will be in this country in a month or two and Garrard will try and arrange for us to meet him to discuss particular US Post Office problems. A very considerable effort is being put into the elucidation of the Small Boy results and it is unlikely that we shall have any useful appraisal before the summer at the earliest.

I suggest we send Mr Sargeaunt such a memo on the lines of the attached draft.

Mr Sargeaunt

E.R. Stanbury
20/12/62

Doc·3. Mr Sargeaunt sends interim reply to doc·1.

Mr Stanbury – to see doc 3. 4/1 7.1.63

I rang to ask Garrard if Bell Telephone man is still expected, and when. I learned from Beards' P.A. that Garrard is in U.S.A., and will be for another 2 weeks. P.H.Pavry 5.3.'63

Mr Stanbury 5/3

Doc·4. Query from Mr Brooker on induced voltages.

Doc·5. Mr Pavry's suggested draft reply to doc·4.

Doc·6. Some observations of Electro-magnetic flash damage resulting from nuclear explosions 7.3.63

(84)
JC&SLtd
Gp782/40
(CODE 18-73)

Doc 7. Mr Pavry asks about visit from Bell telephone Co.

Doc 8. Sir Walter Merton asks for brief note on effects of nuclear explosion on communications and power circuits.

Doc 9. Mr Pavry replies to Doc. 8. 7.2.64.

Garrard rang to say Bell Telephones' representatives will be in this country, and visiting Aldermaston on March 24th. They will be meeting Abercrombie there in the afternoon (he is Reading 55811/7966). I suggested to Mr Stanbury that we should notify Watson (Communications) 2 G.P.O. through him, as Garrard implied they could attend. This would seem to be a good idea, as the meeting is about protecting buried cables from E.M. pulse. I rang Watson to give him preliminary notice. (Bell men will be at Paris Symposium). F.H.Pavry 12.3.

Mr ~~Sargeaunt~~ WOL.

I would like to be told in some detail what is said. I would have attended but am booked all day

WOL. 18.3.64.

I arranged with Watson that he will report to C.S.A. on the discussions at Aldermaston. I will arrange a date for this. F.H.P. 24/3.

Doc 10. Meeting to discuss electromagnetic effects to be held 16th April - brief note sent to Sir Walter Merton + copy to Mr Sargeaunt.

Meeting held on 16th. Mr Sargeaunt
Sir Walter Merton
Mr Firth
" Stanbury
" Garrard
Mr Watson
" Brooker
" Pavry

F.H.P. 20/4.

Reference SAN 62 19/7/1

Doc 11. Copy of Mr Brooker's letter to Mr Ford on meeting with Bell Telephone representative 20.4.64

Mr Pavry FHP. 20/4
Mr Stanbury 21/4
" Sargeaunt.

Doc. 12. Copy of Mr Ford's reply to doc. 11.

Doc. 13. Mr Brooker comments on doc 12 and suggests meeting in June. 12.5.64.

Mr Stanbury 1/6
Mr Pavry FHP 4/6

Doc. 14. Prof. Emeleus enquires about effects of atomic bomb explosions on transmission lines + telephone lines. 3.6.64

Mr Pavry.

Regarding Brooker's letter, I rang him to say Garrard is in U.S.A., probably until the 8th, but I have left a message for him to ring me on his return. I will then see if he can meet Brooker & G.P.O. to discuss any new data he may have. Anyway I think Garrard should be advised of the proposals to air the subject on official committees: we do not want him to think that anyone is trying to put him in a spot, or go over his head. F.H.Pavry 4.6.'64

Garrard rang on return. When ideas & notes sorted he will call and report. FHP 5/6.

Mr Stanbury 8/6

I owed Prof. Emeleus a letter, so I replied (doc 15) to his query: I hope that is all right?

F.H.Pavry 5.6.

Mr Sargeaunt. Thank you very much. I quite agree with your reply. M.A.S.

Doc.16. Prof. Eucleus acknowledges doc.15.

8.6.64

Doc.17. Mr Brooker sends copy of Mr Ford's letter about discussion at meeting on 4th June.

17.6.64

Mr Pavry

Please send copies of docs. 12 & 17A to Mr Garrard.

F.H. 19/6

Registry. Sent. 19.6.64.

Doc 18. Mr Pavry's minute to Mr Sargeaunt about Seminar on electro-magnetic effects.

Doc 19. Mr Pavry sends copy of doc 18 to Mr Garrard & suggests that Mr Hutt should be asked to attend.

Doc.20. Mrs Wilkie replies to doc 19, sends tentative agenda for Air Ministry Symposium & suggests that Mr Pavry should draw up a similar agenda covering Home Office and Civil Defence problems

23.7.64.

Mr Pavry.

I rang to thank Mrs Wilkie, and said we would reply when we have thought about this. You may care to see first, and then I will try to draft what is asked for.

F.H.Pavry 27.7.

Mr Stanbury - doc.20.

Doc 21. Minutes of NWLC meeting held 30th June 1964. Item 4(b) E.M. Flash Hazard to Equipments

Reference SAN 62 19/7/1 3.

I don't think we shall learn much from Chettle's party. I thought it was to be a seminar on E.M. effects, but 10-15 minutes won't get us very far. However I suppose he is right in trying to get the various effects into a proper balance. The important thing is to keep pressing for a meeting where co-ordination can be discussed.

G.R.S. 24/7

Mr Lavery PW

Doc 22. Mr. Brooker sends copy of letter from Mr Fraser.

Doc. 23. Mr. Brooker informs Mr Lavery that Messrs. Ford, Kellenberger & Franklin could be at seminar

Doc 24 Mr Lavery asks Mr. Mowray, Min. of Power for names of those wishing to attend symposium

Docs 25. 26. Mr Stanbury asks Mr Field & Mr R.L. Jones if they will be attending

Doc 27 Invitation agenda

Doc 28. Mr. R.L. Jones & Mr Goldfinger will attend symposium

Doc 29. Sir Lallan Mentor would like to listen-in at Symposium

Doc 30 Mr. Marks would like 3 or 4 places.

Doc. 31 List of those expected to attend the Symposium.

" 32 Revised draft Agenda.

As discussed, I went to talk to Garrard on the 20th.
My draft Agenda was an attempt to tailor the Agenda for the R.A.E. Symposium (see doc. 20) to our needs without departing too far from it.
However, Garrard said our Symposium is our affair, and we can have any Agenda we wish.
We can therefore concentrate on Nuclear Radiation and E.M. Pulse: a revised draft Agenda on the lines of doc. 32 gives the kind of thing we need. Should we discuss with M'Sargeaunt on his return?

F.H. Lavery 24/8

M'Stanbury GRS PW

Code 18-75

I mentioned this to the Sargeaunt and. he is in favour of our revised proposals going forward. He is prepared to open with a short introduction.

G.P.S. 21/8

Mr Savory Fwd

Doc 32 Mr Savory sends Mr. Garrard revised draft agenda for E.M.P. Symposium

Doc 33 Mr Kentaay writes about reps. to attend meeting 28 8 64

Note. There is a description of a 3/8" steel-plate box shield, all round a deep underground structure, in CD. 15095, Part I page 186. F.H.Savory 14/9/64.

Memo. of telephone calls, 21.9.64 to advise about date time & place of Symposium, having confirmed with Garrard that Tues. Oct. 20th 10·30 in Rm. 208 Horseferry is firm:-

1. Comms. Branch (Brooker P.A.) to tell G.P.O. men
2. Marks (message) to ask for names reasonably soon
3. R.L. Jones. (He cannot come, but Collyer will).
4. Hurst, message to P.A.
5. Murray. M.O.P, will tell Power Industry men.

F.H.Savory 21.9.64

Rang Marks 5/10 then Firth's P.A., 6/10, for names. F.H.S. 6/10

Doc 34. Mr Savory writes to Mr Slater about clearances for those attending meeting

Miss Whiteman said Mr Garrard wishes to invite Col. Armour, of Aldermaston: I said we would have no objection. F.H.S. 13/10.

Doc 35. Mr Savory asks Mr Firth for names of people to attend meeting

Mr Law rang to say: Firth, Gelly, Potter Law. I told Mr Bailey F.H.S. 15/10.

Doc 36. Agenda for meeting on 20th Oct + Mrs Wilkies covering note (Doc 37

Mr Briggs, Estabs., rang to say all are now cleared for Secret (with occasional access to Top Secret). F.H.S. 19/10.

Doc 38 List of those expected at meeting on 20th October.

The meeting was held in Rm. 208 as arranged, and there was a very valuable discussion period. Mr Wilkie of A.W.D. agreed to do the secretarial work, and will send us copies of the proceedings. I do not know what you may have said to Group Capt. Chettle after the meeting; but should you write to him — or to Garrard & Popham — thanking them?

F.H.Savory 20/10

Mr Stanbury G.P.S.

Mr Sargeaunt.

Reject. SAN 62 19/7/1 L

Doc. 39. Mr Sargeaunt thanks Gp. Capt Cheffle for E.M. presentation 26.10.64

Doc. 40. Mr Stanbury asks Mr Hartley about effect of EM flash on ROC post survey meter 26.10.64

Doc 41 Minutes of meeting held 20th October 5.11.64

Mr Farley

Please distribute as follows:-

Copies to S.A.B. people who attended, to see for information.

6 copies to Mr Morley, Comms. Branch (with 3 for G.P.O. included).

✓1 copy Mr Firth

✓1 " " Law

✓1 " Mr R.L. Jones

✓1 " Sir Walter Merton

✓1 " Mr Gelly

✓1 " Mr Potter

✓1 " Mr Hurst

✓3 copies Mr A.R.D. Murray, Min. of Power (1 each for Messrs Mott & Witcher).

F.H. Farley 5/11.

Registry:

It is for consideration that we send copies to R.S.A's.? In the particular case of Emeleus we said we would keep him informed: see 14, 15 & 16 on this file. (Mr Wilkie can supply more, if wanted).

F.H. Farley 5/11

Mr Stanbury. I rather think not. There is not much more here than they got at the RSA's Conference from Garrard. If Emeleus is particularly interested I can easily send him a spare copy

Mr Farley

G.F. Stanbury 10/11

Doc 42 Sir Walter Merton's quotes about effects of nuclear explosions on electrical & electronic equipment

(57) WcTY5364 304 11/54 989,000 JC&S.Ltd Gp671/34 REGIMINT) CODE 18-75

Doc. 43 Mr Law asks Mr Ford about effects on telestalk instruments and carrier equipment

Doc. 44 Copy of Mr Ford's reply to doc 43

Doc. 45 Mr Law writes to Mr Batho about the EM effects on power supplies

I mentioned to you to-day the letter that the I.G. has already written to Mr Elgood. I have had a copy put on this file at 42. I don't really see that we can advise him on another minute on the same lines until he has had a reply to this one? (You may also care to see docs. 43-45, on the same topic).

F.H.Pavry 16.11.64

Mr Sargeaunt. Agreed.

I attended a meeting with I.G. and Mr Law. The I.G. drafted a reminder to Mr Elgood, asking him to include all C.D. communications items in his considerations; also a note to Mr Batho asking him if it might be an idea to try and cover Local Authority Controls, by giving guidance on EM risks.

F.H.P. 18.11.64

Doc. 46 Mr Pavry sends copy of doc 41 to Prof Emeleus. 1.12.64

Doc. 47. Prof. Emeleus ~~Dr Lenton~~ acknowledges doc 46 2.12.64

Mr Pavry. F.H.P. 3/12.

Doc. 48. ~~Copy of~~ Sir Walter Worton's minute to Mr Elgood asking for full range of ~~radar~~ communication equipment to be considered.

Doc. 49 Copy of Mr Callyers letter to Mr Batho - effects of EM flash on light & power installations in buildings

You asked about the present position. I have obtained copies of letters written after my meeting with the I.G. and Mr Law on Nov. 18th. There have been no replies so far, but I gather from Mr Law that it is intended to send reminders if nothing comes before mid January.

F.H.Pavry 29/12

Mr Sargeaunt.

Reference SAN/62 19/7/1 5

Doc. 50. copy of Mr Batho's reply to doc 45.

Doc 51. copy of Mr Law's minute to D. Gen. of Comms. enquiring about progress of work relating from I.G.'s minutes (docs 42 + 48)

Doc. 52 Mr Law replies to doc 50.

You may care to see docs. 50 - 52, which I have had copied from file CDP 361/42/1. You will see that Mr Batho, of the Ministry of Public Bldgs. & Works, suggests that, for a start, it would be a good idea to stock spare fuzes. I have discussed this with Garrard, who agrees that it is the most sensible practical move at this stage.
The CDP file came to me with a request from A.2. about what could be said by way of explanation to Local Authorities. Oddly enough, E.N.W. nowhere mentions induced currents in circuits, so I consulted Garrard. It seems that there has, in fact, been no unclassified publication of this information. But Garrard consulted Fakeley, M.O.P., and it has been agreed by them that wording such as I have given to A.2. in my minute (doc 53) is acceptable.

F.H.Lavry April 5th '65

Mr Stanbury GPS
Mr Sargeaunt MM

Mr Law called (May 24th) to enquire about the latest Abercrombie report he had heard about. Mr Stanbury & I said we have not yet had it. Following our talk, I sent to Mr Law copies of Garrard's 'A64/XY/222/05' and F.L.Hill's recent report.

F.H.Lavry May 27th '65

Doc. 54 Covering note to Mr Law with EM paper

(57)
WeTY5364/304
11/54 989,000
JC&SLtd
Gp671.34
(REGIMENT)
CODE 18-75

Doc 55. Note to Mr Brooker on progress of information on Electro magnetic pulse - meeting Suggested for 23rd August.

8.7.65

Mr Sargeaunt
Mr Stanbury GPS 11/8

Doc. 56 Mr. Potter replies to Doc 56. 4.8.65.

Spoke to Mr Potter about this. F.H.P. 12/8

CD 15833

You may care to see the enclosed report by Abercrombie before the meeting arranged for the 23rd. We heard of this report some time ago, and have been trying ever since to get a copy: this one has been lent to me by Brooker; his Branch got it via the Cabinet Combined Ctee on Communications.

The gist of Abercrombie's paper is that he cannot do much until the G.P.O. and Bomber Command co-operate with him. It is however a useful contribution, and discusses (pp. 6 & 7) comparision with lightning.

F.H.Lavery 16/8

Mr Stanbury GPS 19/8
Mr Sargeaunt.

Doc 57 Note of arrangements for meeting on 23rd August.

The meeting was held on Aug 23rd, as arranged, though Mr Sargeaunt and Mr Stanbury were unable to attend.

Mr Garrard described the expected Effects Manual, which may be available in draft later this year. But the Engineers Manual will not be written for some unspecified time.

During the course of questions from Mr Elgood & Mr Morley, it appeared that co-operation between the G.P.O. & Aldermaston has not been very good; and that early solution of the general communications problem is not to be expected. But Mr Garrard said that Aldermaston can, when they know the general geometry of a simple radio problem, such as the 'Hill-top' wireless station, get reasonable estimates by analogue computer. In more complex problems, the U.S. solution has been to use portable simulators, or take portable equipment to large static simulators.

F.H.Lavery 23/8/65

Mr Sargeaunt See also note by Dr McAulay. (Doc 58)
" Stanbury GPS 25/8

Doc 59 NWLC/P(65)3 EMP Workshop at Santa Barbara
21st - 30th June 1965

21 9 65

Mr Barry. FH. 21/9

Doc. 60. Minute on EM Pulse Knowledge as sent to Sir Walter Heaton, Mr Gelly, Mr Firth & Mr Lloyd
(See also minutes on file SAG 10/136/2)

Doc. 61. Sir Walter Heaton acknowledges doc 60.

Doc. 62. Mr Garrard comments on E.M. papers.

7.2.66

Mr Barry

Doc 63. Mr. Garrard sends paper on Basic Principles EMP protection

10.2.66.

Mr. Barry

Doc. 64. Mr Garrard returns original of NATO paper & sends Sunde's report on loan.

Doc 65 Mr Barry sends Sundes paper on loan to Mr Brooker

Doc. 66. Copy of correspondence with GPO

Doc 67 Covering note from Mr Brooker with doc 66 + 66A enquiring about effects on instruments.

Mr Stanbury EMP/3/3
Mr Sayle-Davis } to see doc 67.
(M 21/3/

Doc 68 Note absent inclusion of A1 division in future EMP meetings.

Doc 69. Mr Lowry sends copies of doc 65 & to Mr Nicholson

Doc 70. Mr Lowry sends Sunde's report to Mr Law with copy of his minute to Mr Brooker + Mr Brooker's reply

Doc 71. Mr Law replies to doc 70
4.4.66.
Mr Lowry

Doc 72. Mr Lowry replies to doc 71.

Doc 73 Mr Lowry asks Mr Garrard for comments on doc 71 and returns Sunde's paper
5-4-66.

Doc 74. Mr Law writes about work at AWRE
21.4.66
Mr Lowry

Doc 75 Mr Garrard replies to doc 73.

Doc 76 Mr Lowry sends copy of doc 75 to Mr Law.

I made a short statement about EMP at the C.E.G.B. Study 'Paternoster' on 28.4.66, explaining that we had kept Messrs Mott & Whitcher informed. J.M. 2/5/66.

Doc. 77 Copy of note from Mr Garrard about DrSA report.

Doc 78 Mr Pavry sends copy of Mr Garrard's RSA Conf talk to Mr Wilkinson

Doc 79. Mr Pavry refers to doc 75 & sends copies of correspondence.

Doc. 80. Mr Spencer asks if Secret paper may be shown to Messrs Holt & Whitcher

28 7.66

Mr Pavry I rang him to say 'yes'. F.Hlavsy 29/7

Doc 81 Mr Spencer has passed copy of part of Secret paper to Messrs Holt & Whitcher

Doc. 82. M^r Gelly asks what progress on EMP since January

I called on M^r Gelly & discussed this: when M^r Brooker is available we will meet again, with him, to find out whether the E.W. Cttee (M.O.D.) have put the question of the UKWMO network to Abercrombie. F.H.P. 10/10

Doc. 83 Copy of letter from Mr. Gelly to Mr Ferris 11.10.66

Mr Pavry. FW Seen GRS 20/6

M^r Brooker called to discuss Doc. 60 – of 28.1.66 – which has only now come his way I gathered that G.P.O. claim that they long ago gave Abercrombie a mass of data to assess, but have had no advice from him. I said that Abercrombie had quite happily given massive help to Norway, and he should be made to do as much for this country. I suggested that the way

might be for the Electronic Warfare Committee to go direct to the Director of A.W.R.E.

F.H.Pavry 7th Dec.'66

Discussed E.M.P. with Prof. Barlow R.S.A. on 8.12.66
See minute on this file (doc 87)

FHP 12/12

Doc 84 Mr Pavry asks Mr Abercrombie for copies of EMP paper prepared for Norwegians

Doc 85. Mr Wolfe replies to doc 84 + promises to send 20 copies of the report

Doc 86. Mr Pavry acknowledges doc 85 + requests further report by Abercrombie

Doc 87. Memo of interview with Prof Barlow

Doc. 88. Copy of Mr Brooker's letter to Mr Wright asking for up to date information about EMP.

Doc 89 Mr Brooker's covering note with doc 88

Doc. 90. Copy of Air Commodore Cresswell's letter to Mr Gelby referring to DASH paper on EMP.

Doc 91. Mr Pavry sends copy of doc 85 to Mr Hurst + comments on "33 Basic Principles of EMP Protection"

Doc 92 Copy of Mr Garrard's letter to Prof. Barlow

Doc 93 Mr Pavry sends (HURLE) 'EMP' paper to Mr Brooker and Mr Gelby

Reference SAN 62 19/7/1

Doc 94 Herbottle sends draft report on EMP + enquires how many copies will be required

Doc. 95. Mr Pavey request 8 copies of report.

Doc 96. Notes of meeting held 10th January

Doc. 97. Col Barnes has arranged for MOD EMP report to be sent when available

Mr Pavey FSH 6/2

6. 2. 67

Doc. 98 Mr Landrock acknowledges note of meeting held 10th Jan. - would like rep. from A.I.A.W. to attend April meeting

15. 2. 67.

Mr Pavey.

Please send a copy of Mr Abercrombie's paper, CD 16445, to Prof. Barlow on loan. I take it there is no problem of security. FSHavey 15.2.

Registry. CD 16445 sent on loan 15. 2. 67

I spoke to Col. Barnes, thanking him for his letter (97). The report is written, but being discussed by various committees. It should be available to us by end of March. FSH. 7/3/67.

Docs 99 + 100 Mr Pavey writes to Building Research Station and Electrical Research Assn. requesting information on EMP effects

Doc. 101. Mr Day replies to doc. 99.

Mr Pavey - Dr Golde rang in response to doc. 100, saying we could discuss with him, or with a Mr Jackson.

F.H. 16/3

Doc·102 Mr Parry acknowledges doc 101

Doc·103 Mr Parry sends copies of docs 101 + 102 to Mr Garrard, comments on ERA's reply + requests ~~further~~ consideration of what action should be taken.

Doc 104. Proposed arrangements for meeting on 13th April 1967

Doc. 105. Notes of replies to doc 104

Doc. 106 Mr Ackroyd suggests alternative date for meeting.

Doc. 107. Mr Parry replies to doc. 106.

Doc 108 Mr Ackroyd hopes that meeting can soon be arranged

28.4.67

Mr Parry. PH 19/5. Please B.F. 1.6.'67

Experimental techniques for simulation of electromagnetic pulses [illegible]
AW/AW/EN +/cc

Electromagnetic pulses [illegible]
AW/AW/EN 3/66 + Appendices A, B + C

Doc 109 Note of meeting to be held 14th July.

Doc 110 Mr. Parry asks Mr. Kelly to find out if Mr Dallas Morton will be attending meeting

Doc 111 Mr. Parry writes to Mr Taylor enclosing copies of Docs. 96 + 109.

Reference SAN 62 . 19/7/1 . . . . .

File Closed
Continued on file SAN 62 19/7/2

111

7.2

21st June, 1967.

Dear Taylor,

... I am enclosing a note confirming the date and place of the meeting we spoke about. If you have not been to this office before you come into the north entrance to Horseferry House (which is in Horseferry Road) and come up to the 5th floor; the messenger will then show you where Room 542 is.

You may not have seen the note of our last meeting in January, so I enclose a copy for your information. I expect you will show this to Dr. Hanbot.

Yours sincerely,

F.H. PAVRY.

H.K. Taylor, Esq.,
D.Sc.3., Ministry of Defence
Main Building
Whitehall, S.W.1.

Mr. Colly
Warning and Monitoring Branch

Electro-Magnetic Pulse

Sir Walter Perton may wish to attend the meeting on July 17th. Would you talk to him about it, and let me know if he will be coming?

F.H. PAVRY.

21st June, 1967.

Scientific Advisers
Branch.

Electro-Magnetic Pulse

This is to confirm the arrangements made by telephone for a meeting to be held on Monday, 17th July at 10.30 a.m., in Room 542, which is in this Branch.

This follows our meeting of January 10th, 1967, of which you will now have received record. I have sent copies of this confirmation to the following:-

Colonel F.G. Barnes - Cabinet Office
Mr. D.J. Garrard - Ministry of Technology
Mr. H.F. Taylor - D.Sc.3, Ministry of Defence
Mr. J.P. Celly - Home Office, Warning and Monitoring Organisation
Mr. N. Morley - Home Office, Communications Branch
Mr. J.L. Brooker - " -
(3 extra copies for G.P.O. representatives)
Mr. L.R. Jacobs - Home Office, A.1 Division.

F.H. Perry

21st June, 1967.

Scientific Adviser's
Branch.
Horseferry House
S.W.1.

Mr. Pavry
Scientific Advisers Branch

Electro Magnetic Pulse

Thank you for your note on E.M.P. dated 5th April 1967.

Mr. Rodgers of the Post Office Engineering Department has made contact with the Ministry of Aviation, but little progress was possible because of the lack of practical information on the subject. They and the Communications Branch are therefore anxious that the next meeting is not too long delayed.

Perhaps you could advise me when such a meeting is likely to take place, please.

E. J. F. Ackroyd

27 April 1967

Communications Branch

A H Perry Esq,
Scientific Advisers Branch.

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Mr Perry,

Electric Hydraulic Pile.

Regarding your note proposing a
meeting on 15th April 61, which I
have just learnt was free, proof of
I have discussed the possibility
of pursuing our enquiry into with
the Post Office, who, after all may
a safe period for absorbing it.
awarded MoA report, are thinking
in terms of the second week in
May If you consider this as

Barnes suggests we include K Taylor H.O.D. D Science 3 next meeting

105

advised about postponement. left message 4/4.

[illegible] ← advised about postponement. left message 4/4.

Col. [illegible] ← . Wants to postpone

Mr. Garrard ← . Spoke Morley 4/4. also about G.P.O. not getting in touch with Garrard.

Mr. [illegible]

? → Mr. Gelly ✓ 31/3 ← advised Gelly's P.A. 3/4 about postponement.

[illegible] Pulse

At our [illegible] on [illegible] January I [illegible] call [illegible] in April.

[illegible] (a) [illegible] (b) [illegible] held [illegible].

[illegible]) [illegible], [illegible].

Will you please [illegible] if this is convenient to you? If not, please [illegible] days in that week.

Will Mr. [illegible] please consult G.P.O. [illegible]?

F. H. Parry

Col.
Mr. Gairard
Mr. Brook
Mr. Colly

[illegible]

[illegible] on 10th January I was asked to call [illegible] in Cecil.

[illegible] (a) [illegible] (b) [illegible], but i[illegible]

[illegible] in his office [illegible] Thursday, 13th April.

Will you please let me know if this is convenient to you? If not, please indicate alternative days in that week.

[illegible] consult G.P.O. [illegible]

F.H.Lawry

[illegible]

Mr. Stanbury
Col. Barnes
Mr. Garrard
Mr. Brooker
Mr. Gelly

Electro-magnetic Pulse

At our meeting on 10th January I was asked to call another in April.

I have not so far received the material listed at (c) and (d) in the 'actions', but it might be useful to hold a meeting so that progress can be reported.

It is suggested we meet again in this office (Room 542) at 2.30p.m. on Thursday, 13th April.

Will you please let me know if this is convenient to you? If not, please indicate alternative days in that week.

Will Mr. Brooker please consult G.P.O. representatives?

F. H. Pavry

30th March, 1967

Scientific Adviser's Branch
(Tel. 834 6655 ext.531)

Scientific Adviser's Branch,

SAN 19/7/1 17th March, 1967.

Dear

Please see the enclosed reply to the letter I wrote to B.R.S. on Barlow's advice: I sent you a copy. A foreign Dr. Golde (pronounced Golda) rang from E.R.A. to say that he or a Mr. Jackson would be willing to discuss, but they are busy off and on at international conferences. Dr. Golde was inclined to doubt whether their work was relevant, but if we wish to talk we are to ring their shared P.A., a Mrs. Sills. It might save time wasted possibly on a visit if you rang Golde to ask his reasons for his doubts.

Will you consider what, if any, further action on this subject is worth taking? If you decide to visit B.R.S. or E.R.A. and want me to come along, I am fairly free except from April 26th to the end of May.

Yours

F. H. Pavry

D. J. Garrard, Esq.,
Ministry of Aviation,
A.W.D.2(Effects),
Room 508,
Prospect House,
80 New Oxford Street,
London W.C.1.

Scientific Adviser's Branch, 102

SAM 19/7/1
A203/64/38

17th March, 1967.

Dear Sir,

Thank you for your letter of the 14th. I will first discuss your letter with our adviser on electro-magnetic problems, and will then consider any further action.

Yours faithfully,

F. H. Pavry

The Director,
Ministry of Technology,
Building Research Station,
Garston,
Watford,
Herts.

GL

101

Ministry of Technology
BUILDING RESEARCH STATION
Garston, WATFORD, Herts.
Telegrams: Research, 'Phone, Watford
Telephone: Garston (Herts) 4040

Please address any reply to
THE DIRECTOR
and quote: A203/64/38
Your Reference

14th March 1967

Dear Sir,

Thank you for your letter of the 6th March.

The only reference that I can find on the attenuation of e-m waves by a wire grid is in a paper entitled "Some technical aspects of microwave radiation hazards" by W.W. Mumford, Proceedings of the Institute of Radio Engineers, Vol.49, pp 427-447, February 1961. This paper also contains a nomograph for the calculation of attenuation due to a grid where the wire radius, the wire spacing, the input power and the wavelength are known. This wavelength would presumably be the wavelength in the medium and would be dependent on the dielectric constant of the building material.

Some theoretical work has been done at B.R.S. on the prediction of attenuation of microwaves by building materials. This work entails the prediction of the dielectric constant of the material when various amounts of water are present. There are some internal notes on this work available.

It would seem then that if the B.R.S. work can accurately predict the wavelengths in a medium surrounding a grid and if this wavelength is used in conjunction with the data given in the cited paper that you should be able to calculate the amount of power getting through to your equipment. Perhaps even, you could calculate the size of reinforcement grid necessary to give you optimum protection.

If you wish to discuss the matter further, you should have a word on the telephone with our Mr. J.L. Smith of the technical advisory service.

Yours truly,

EWF pp A.G. Day

A. G. Day
for Director.

F.H. Pavry Esq.,
Scientific Advisers Branch,
Home Office,
Horseferry House,
Dean Ryle Street,
London, S.W.1.

Scientific Adviser's Branch,
HOME OFFICE
Horseferry House, Dean Ryle Street, LONDON S.W.1
Telephone: VICtoria 6655, *ext.*
Telex: 24986

Our reference: SAN/62 19/7/1
Your reference:

6th March, 1967.

Dear Sir,

One of our Civil Defence problems is the protection of communications and power equipment from the electro-magnetic pulse generated by the explosion of a nuclear weapon.

In the literature on this subject it has been suggested by some that the reinforcement in the walls and roof of a concrete structure, such as a communications centre, could help to protect equipment in the structure: others have doubted the value of such protection.

I understand that your Association has conducted research in the allied field of lightning protection, and so I am writing to ask if you have any information or advice on the problem I have briefly outlined.

I would, of course, be pleased to discuss the matter in more detail if you can help us.

Yours sincerely,

F. H. Pavry

Copies sent to
Mr Garrard
Mr Selby
Mr Brooker
Mr Cambrook A

The Director,
Electrical Research Association,
Cleeve Road,
Leatherhead,
Surrey.

Scientific Adviser's Branch,
HOME OFFICE
Horseferry House, Dean Ryle Street, LONDON S.W.1
Telephone: VICtoria 6655, *ext.*
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I have recently had a brief discussion with Professor Barlow of University College, who is one of our Regional Scientific Advisers, on this problem, and he advised me to write to you. He suggested this because of research you are doing on the study of materials by penetrating radiation.

Could you please advise me whether you think that this research is relevant to our problem? If so, I will of course be pleased to discuss the matter in more detail.

Yours sincerely,

F. H. Pavry

The Director,
Building Research Station,
Garston,
Watford,

9

Scientific Adviser's Branch,
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Horseferry House, Dean Ryle Street, LONDON S.W.1
Telephone: VICtoria 6655, *ext.*
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F. H. Pavry

Copies sent to
Mr Gerrard
Mr Kelly
Mr Brooker
Mr Cambrook A

The Director,
Building Research Station,
Garston,
Watford,

Scientific Adviser's Branch,
HOME OFFICE
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Telephone: VICtoria 6655, *ext.*
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I would, of course, be pleased to discuss the matter in more detail if you can help us.

Yours sincerely,

F. H. Pavry

The Director,
Electrical Research Association,
Cleeve Road,
Leatherhead,
Surrey.

JK

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Ref. CDN/64 361/42/1

Mr. F. H. Pavry
Scientific Advisers . Branch

Electro-Magnetic Pulse

Thank you for the copy note of the meeting held on 10th January to discuss progress on the E.M.P. question.

The subject is of interest to A1 Division in relation to communications for the Control System and we should be glad to be given the opportunity of attending your meeting in April, when you expect further information to be available.

A.O. Cambrook

15th February 1967

A1 Division
HORSEFERRY HOUSE

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CABINET OFFICE
LONDON, S.W.1

WHITEHALL 5422

F G James

HOME OFFICE

SCIENTIFIC ADVISER'S BRANCH

Notes of a meeting held on 10th January, 1967, in room 542, Horseferry House to discuss:-

Electro-magnetic Pulse

Present:-	Mr. Stanbury	Scientific Adviser's Branch, H.O. (Chairman)
	Col. Barnes	Cabinet Office
	Mr. Garrard	A.W.D.2., Ministry of Aviation
	Mr. Wright)	G.P.O.
	Mr. Rogers)	
	Mr. Gelly)	Warning and Monitoring Organisation, H.O.
	Mr. Potter)	
	Mr. Lane)	
	Mr. Morley)	Communications Branch, H.O.
	Mr. Brooker)	
	Mr. Pavry	Scientific Adviser's Branch, H.O.

Mr. Stanbury said he had called the meeting to bring all concerned up-to-date on E.M.P. He had been prompted to do this because of two communications from Mr. Gelly:-

(1) a minute dated 29th September 1966, in which he said he was trying to establish the present position, following a minute from the Chief Scientific Adviser in January 1966. (In that minute C.S.A. had reported the conclusion of the Nuclear Weapons Lethality Committee that the research effort on E.M.P. was inadequate.)

(2) a letter dated 26th December 1966 from the Commandant of the R.O.C. to Mr. Gelly, about a lecture given by Mr. Abercrombie at Fighter Command. The Commandant reported that Mr. Abercrombie had said that basic technical data were freely available in an unclassified American report, and that local technical staffs could, with the help of that report, solve their problems.

Mr. Stanbury dealt with this second item first, saying that there had, it seemed, been a misunderstanding at Mr. Abercrombie's lecture. The Scientific Adviser's Branch had been aware of the report in question for some time, since Mr. Garrard had kept them informed of his efforts to produce an edited version of low classification: but the report itself has all along been extremely highly classified. Mr. Abercrombie had been asked about his lecture, and denied that he had said the report was unclassified.

As regards a lowly-classified version of the American report, Mr. Garrard said he had completed his draft, and it is now with the American authorities, whose approval is necessary before it can be made available. He hoped that approval would be forthcoming, and that it might be possible to issue the report within a few months, but it depended on how quickly the U.S. authorities acted.

With regard to Mr. Gelly's first point, Mr. Garrard said that (following the comments of the N.W.L. Committee on the lack of adequate research) the Ministry of Defence Weapons Defence Committee had set up a Working Party to advise on how to solve the problem.

Col. Barnes said he was associated with a separate study of E.M.P. by the Ministry of Defence. A report was soon to be made available through the Cabinet Communications Electronics Space Committee, and Col. Barnes said he would try to make copies available to the Home Office.

There was a discussion on the extent to which the effect of E.M.P. on communications and Civil Defence equipment had so far been assessed. It seemed that the G.P.O. have given the M.O.D. a great deal of information on their systems for this purpose, but it is not clear whether this has been examined in the E.M.P. context. It was thought that A.W.R.E. have not studied the G.P.O. problems.

Mr. Stanbury said that it was necessary to consider how the various users' problems might be studied when the new data from the U.S.A. and the M.O.D. was received. He suggested that the G.P.O., for example, might need assistance in studying their problems.

It was agreed that it would be useful to hold another meeting in April, when the new data should be available. Meanwhile, the following actions were decided:-

✓ (a) Mr. Brooker to send to G.P.O. a copy of the "Basic Principles of E.M.P. Protection".

✓ (b) Mr. Garrard and Mr. Wright to discuss G.P.O. problems.

× (c) Col. Barnes to supply Home Office with report when available.

✓ (d) Mr. Garrard to supply Home Office with report when available.

? (e) G.P.O. to consider the need for technical assistance.

✓ (f) Mr. Pavry to co-ordinate, and arrange the meeting in April.

Sent on 2.2.67 C.

Col. Barnes
Mr. Garrard
Mr. Wright
Mr. Kelly
Mr. Brooker.
Mr. Millerson
Mr. Hurst
Mr. Sargeaunt
Mr. Benn.

BID

RESTRICTED

HOME OFFICE

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	Mr. Rogers)	
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	Mr. Morley)	Communications Branch, H.O.
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	Mr. Pavry	Scientific Adviser's Branch, H.O.

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Scientific Adviser's Br.
Home Office.
12th Jan. 67

AWRE O-5/67

Dear M' Wolfe

[illegible] for [illegible] of the 10
I would say that [illegible]
I am returning the draft [illegible]

[illegible]

[illegible]

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UNITED KINGDOM ATOMIC ENERGY AUTHORITY

TELEGRAPHIC ADDRESS:
ATEN, ALDERMASTON, READING
TELEX: 84104
TELEPHONE:
TADLEY 4111
NEWBURY 1800
BASINGSTOKE 3281
EXT. 7223

ATOMIC WEAPONS RESEARCH ESTABLISHMENT,
Building F6.2
ALDERMASTON,
BERKSHIRE.

OUR REFERENCE:
YOUR REFERENCE:

16 January

Dear Mr Irving

AWRE Report O 5/61

I telephoned your office today to say that if you would like copies of O 5/61, which is a mathematical report from which A. Buchanan's stable about electron ways

The report is still in draft form and the author is working upon it at the moment; although there are copies of the central distribution (a) you get copies of the central distribution without having to wait for more; (b) we do not have to reply to request!

The wording of O 5/61 is Unclassified Limited Distribution (the LD meaning means that the author wishes to publish separately

I attach a copy of the draft and shall be glad to know how many copies of the printed version you would like

Yours sincerely,
Dennis Wolfe

(D H Wolfe)

Minute also sent to Mr Gelly without Ps

F.H.P

Scientific Advisers Branch
Home Office

92

AWD.2 (Effects),
Room 508,

2 92

YY/3 6/04

23rd December, 1966

Dear Professor Barlow,

Thank you for your letters. I too will look forward to a further discussion on E.M.P. In the meanwhile here are a few quick thoughts on some of the points you raise.

In mentioning an analogy with lightning protection I was assuming, I think with justification, that in the cases with which we are concerned the total energy in the E.M. pulse would be comparable with that from a lightning flash. This will only very rarely be an underestimate, possibly by a small factor, and will generally err on the conservative side from the point of view of design. We also noted the implications of the relatively steep leading edge.

You are of course entirely correct in pointing out that the E.M. pulse is only one of a number of more or less simultaneous stresses applied to a particular system. I would be very happy to discuss these other aspects with you anytime, but in the meanwhile I can assure you that they occupy a large part of our attention.

/I

Professor H.W. Barlow, F.R.S., M.I.E.E., M.I.Mech.E.,
University College London,
Department of Electrical Engineering,
Gower Street,
W.C.1.

I am not quite sure whether I have correctly understood your reference to the use of aerials in the dual role of lightning protection. I wonder if it is relevant to point out that, unlike the very localised lightning strike phenomena, the E.M. pulse field is present everywhere, and becomes a nuisance in proportion to the length of metal or size of loop exposed to it. I have not expressed that very well, but I think you will see what I mean.

Your low-loss waveguide development is certainly very interesting, and I am sure Otway Mayry and I will be giving it further thought in the context of our various problems. Thank you for pointing out the possibility of making arrangements through the N.R.D.C.

With best wishes for the New Year.

Yours sincerely,

(D.J. GARRARD)

SAN/9/7/1

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HOME OFFICE

[redacted]

21 [redacted]

[redacted]

From: Air Commodore J.N. Greswell, CBE,DSO,DFC.,

90

HEADQUARTERS
ROYAL OBSERVER CORPS
Bentley Priory, STANMORE, Middlesex
Telephone: Bushey Heath 4000, ext. 206

Please address any reply to
THE COMMANDANT
and quote: ROC/JHG
Your reference:

20th December 1966

Refers to EMP Working Group's report, "Electromagnetic Pulse Phenomenology and Effects (U)"; DASIAC Special Report 41 (DASA 1731), April 1966, classified: "Secret Restricted Data".

(DASA 1731 = AD372860L.)

Mr. J.P. Gelly
Warning & Monitoring Branch
Home Office
Horseferry House
Dean Ryle Street
London S.W.1

Dear John,

I recently attended a talk by Mr. Abercrombie of A.W.R.E. on the effects of E.M.P. etc generated by a nuclear explosion, on communications and on electrical and electronic equipment and cables. He said that much research on this had been done by the Americans and that the basic technical data is contained in an unclassified report issued by them reference DASA 731 entitled "Electro-Magnetic Pulse Phenomenology"

I understood that this report contains a very great deal of technical information, graphs, tables etc, from which it is possible for users to interpret the possible effects of E.M.P. on their equipment and communications.

Mr. Abercrombie's lecture dealt only with the principles of the E.M.P. phenomena as contained in the American reports and he emphasised that, because the physical layout and conditions of the communications and equipment of each user varied so widely, it would be inappropriate for him or A.W.R.E. to undertake studies of effects on behalf of users. He quoted the case of a RAF Command to whom he had given his lecture, later sending him a long list of questions, all of which could have been answered by the Command's technical staff by reference to the data contained in the American report. I gather that this apparant lack of co-operation has led to certain ill feeling and has wrongly been interpreted that only scant information exists about E.M.P. The fact is that only limited work has been done on applying the known data to communications networks. In my opinion this work is not properly the task of A.W.R.E. but should be undertaken by local technical staffs, based upon data provided by organisations such as A.W.R.E.

I know you are concerned about the effects of E.M.P. on our communications, and I thought the above might be helpful. It seems to me that, if S.A.B. could get hold of a copy of DASA 731, much work could be done in this respect. I am told that only a few copies of the report exist in this country but no doubt Home Office could get more from America. I have tracked down one copy with AWD2 in the Ministry of Aviation.

Yours ever

J.H. Greswell

M^r Gelly showed me this letter on Dec. 22^nd. I explained that there has been some misunderstanding. DASA 1731 (not 731) is the U.S.

Mr Pearce FYI 15/12

Jan may wish to have this copy of my note to Mr Wright of GPO – a copy also goes to Mr Kelly.

Thank you for the loan of CD(61)43/4 returned with this note. I'll keep for a little longer if I may the NATO paper

AC/158 – WP/11

13/12

CONFIDENTIAL

88

COM 64/71/41 *Copy for Mr Parry SAB*
[illegible]/1.3

13 December 19[illegible]

[illegible] Wright,

[illegible]lectro - [illegible]netic Pu[illegible]

Perhaps the most significant feature of this subject i[illegible] the lack of inform[illegible]tion [illegible]ut it. Indee[illegible] on[illegible] [illegible] [illegible] "[illegible] [illegible]ut [illegible] is that it exists". I'm prompted to write in this fa[illegible]ion [illegible] I [illegible] very [illegible]ly just seen a note by our Chief [illegible]cientific [illegible]r of the [illegible] ... the (Nuclear Weapons Lethality) Com[illegible]ttee has recently pre[illegible] [illegible]y of current knowledge of nucle[illegible] effects and the adequacy o[illegible] [illegible]rt in [illegible] field." Th[illegible] survey [illegible] sent to all the chi[illegible] [illegible] [illegible]

[illegible] see from the first conclusion of the survey whic[illegible] [illegible] [illegible] of opinion regardin[illegible] [illegible]portance of the subject [illegible] c[illegible] in our knowledge of the vulnerability of e[illegible] [illegible] equipment to nuclear radiation [illegible]nd electro [illegible]gnetic fla[illegible] [illegible] essential to [illegible] study of many systems and complex t[illegible]. [illegible] currently devot[illegible] to this investigation is insufficient to obt[illegible]in t[illegible] [illegible] in r[illegible] time".

At this pre[illegible]ent time [illegible] [illegible] to [illegible], [illegible] [illegible]uld exceed th[illegible]t of the Service depart[illegible]. [illegible] t[illegible] [illegible] [illegible]ith th[illegible] [illegible]ittee of C.C but it occur[illegible] to [illegible] that you are r[illegible] level on this su[illegible]-committee and c[illegible]uld [illegible], in th[illegible]t forum, for [illegible] attention to be given to this matter: [illegible] necessary to overcome cert[illegible].

However thin[illegible], I [illegible]r if y[illegible] could let [illegible] the[illegible] [illegible] any [illegible] since Ford [illegible].

[illegible] you could also let me know what has happened to the sugg[illegible]n Ford [illegible] letter to me on the 6th September 1965 that Abercrombie of AWRE should be [illegible] to study the effects of EMP on a part of the Warni[illegible] [illegible]. [illegible] [illegible] to the [illegible], [illegible] [illegible]t trace my reply so I sent him a copy the next d[illegible].

[illegible] believe th[illegible]t th[illegible] [illegible] by [illegible] for [illegible]ion. We unfortunately, are still in th[illegible] [illegible]rk on what, if any, progress

/has

B. T. Wright Esq
Planning Branch D53
Inland Telecommunications
G.P.O. Headquarters
St. Martin's-le-Grand

CONFIDENTIAL

has been made in the last year. I feel we should do something to protect our vital circuits by having them fitted with lightning arresters (gas discharge tubes) but before asking you to do so, I think we should ensure that there are the best protective arrangements we could make.

Yours sincerely,

(J. L. [illegible])

Mr Stanbury

Memo. of Interview with Prof. Barlow. (8.12.66)

As suggested by you, I went to see Prof. Barlow with Mr Garrard, to give him an introduction to our interest in the effects of the Electromagnetic Pulse. Mr Garrard gave him a summary of the technical background and agreed to supply him with appropriate reports, which he would send through this Branch.

Prof. Barlow in turn told us of research he is doing on Wave Guides. Mr Garrard said there is quite a possible Defence application, since Wave Guides provide a possible means of conveying communications into structures ~~by means~~ which could be immune to E.M.P. effects.

Prof. Barlow is working with the G.P.O. on proposals for a long Wave Guide – about a mile long – at Martlesham Heath. He implied that it would be useful to him if we could, in any way, lend support to this project, even if we did not necessarily wish to support it financially.

Would you consider what, if anything we can do?

Mr Garrard was obviously better aware of the possible applications of Wave Guides, and I am sure he would be pleased to join in any discussions you may decide to initiate.

F.H. Lavry

Dec. 12th '66

Memo. of Interview with

86

8th December 1966

Dear Mr. Wolfe,

[illegible] letter of the 2[illegible] November.

[illegible] six copies of the report to come to this Branch.

[illegible] a copy of [illegible] report [illegible].171.45. without success. Could you let [illegible]

[illegible],

[illegible]

[illegible] Wolfe, Esq.,
[illegible],
[illegible],
[illegible],
Aldermaston,
Berkshire.

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

85

TELEGRAPHIC ADDRESS
ATEN ALDERMASTON, READING

TELEPHONE
~~READING SEAL~~
NEWBURY 1800
BASINGSTOKE 1960
HEATH END 387
T ~~READING~~ 4111
EXT. 7223

OUR REFERENCE

YOUR REFERENCE

ATOMIC WEAPONS RESEARCH ESTABLISHMENT,
Building F6.2
ALDERMASTON,
BERKSHIRE.

28 Nov 66

Dear Mr Pavey

AWRE report on EMP effects

This note is to confirm my telephone call of 28 Nov 66.

Thank you for the copy of the letter to Abercrombie. His report, to which you refer, is being printed as an AWRE Report (Ref No O-68/66), and 20 (twenty) copies will be issued to the Nato and Ivor Group on War Headquarters (graded NATO-Secret).

Yours sincerely,

Bernard Wolfe

(B.W. Wolfe)

[illegible], 1961.

[illegible],

[illegible] produces [illegible].

[illegible] wanted for members of [illegible].

[illegible] roup on [illegible]barrassing [illegible].

[illegible], I must at [illegible] name accept[illegible].

[illegible],

[illegible] Ivy

[illegible]. D. Abercrombie, [illegible].

With Compliments
of Mr.Gelly

Warning and Monitoring Branch
Home Office
Horseferry House
Dean Ryle Street
S. W. 1

Tel: VIC 6655 Extn. 680

CONFIDENTIAL

COPY

CDA/59 36/18/2

Mr. R. H. F. Firth
Communications Branch

Electro-Magnetic Pulse

I am trying to establish the present position on this subject and have written to the Chief Scientific Adviser asking him to let me know what progress, if any, has been made on the scientific side since he circulated his note of 28th January 1966 (ref.SAG/62 10/156/2).

2. Would you, therefore, be good enough to bring me up to date on the position so far as Communications Branch is concerned and, in particular, advise me on the following points:-

(i) Was Elgood able to raise the question of progress in the EMP field with the Chairman of the Electronic Warfare Sub-Committee, as indicated in Ford's letter of 6th September 1965 to Brooker (ref.COM/64/71/4/1), and if so with what result?

(ii) Has Brooker heard anything further from Ford about the latter's letter of 12th May 1966 to Chew of the Ministry of Defence (Air)?

(iii) What has happened to the suggestion first made by Ford in his letter of 6th September 1965 to Brooker and later repeated to Brooker in his letter dated 22nd March 1966, about studying the effects of EMP on the warning and monitoring network?

3. Some three years have passed since Warning and Monitoring first raised the problem of EMP; I am sure you will agree that it is time we took stock and decided what, if anything, can be done to produce some results.

(Signed) J. Gelly

29th September 1966.

Warning and Monitoring Branch

CONFIDENTIAL

CONFIDENTIAL

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CDA 36/18/2
59

SAG/62 10/156/2

Mr. H. A. Sargeaunt
Chief Scientific Adviser

Electro-Magnetic Pulse

I am trying to establish the present position on this subject and should be most grateful if you would let me know what progress, if any, has been made since you circulated your note of 28th January 1966.

29 September, 1966.

Mr. Parry
Mr. Sargeaunt would be glad if you could deal with this direct and let him know if there is anything to report.
30/9

Warning and Monitoring Branch
Home Office
Horseferry House

CONFIDENTIAL

SECRET

81

MINISTRY OF POWER
Thames House South, Millbank, LONDON S.W.1
Telephone: Abbey 7000

Our reference: WP 15/9/01 Pt.2

16th August, 1966.

Your reference:

Dear Pavry,

E.M.P. Effects

I return herewith NATO Secret booklet SA-6-2-04(SUS)1, Copy No. 240 - The Effects of Nuclear Weapons on Underground Structures.

As agreed with you on the telephone to-day, we have now sent copies of pages 21-38 to Messrs. Mott and Whitcher.

Yours sincerely,

(H. L. Spencer)

CC67/MD/13

F. H. Pavry, Esq.,
Scientific Adviser's Branch,
Home Office,
Horseferry House,
Dean Ryle Street,
London, S.W.1.

VT

SECRET

SECRET

80

MINISTRY OF POWER

Thames House South, Millbank, LONDON S.W.1

Telephone: Abbey 7000 / 1007

Our reference: 15/9/01 Pt.2

22nd July, 1966.

Your reference:

Dear Pavry,

E.M.P. EFFECTS

On 15th June you sent us on loan Copy No. 240 of a document NATO SECRET SA-6-2-04(SUS)1 - Seminar on The Effects of Nuclear Weapons on Underground Structures - to see pages 21-38 which relate to E.M.P. Effects.

Is there any objection to Messrs. Mott and Whitcher of the Electricity Supply Industry having sight of this document before we return it to you? Both have been brought in on this subject and, as you know, have received papers from you. Both have responsibilities for defence planning arrangements in their industry and are security cleared to see documents up to and including SECRET classification.

Yours sincerely,

(H. L. Spencer)

F. H. Pavry, Esq.,
Scientific Adviser's Branch,
Home Office,
Horseferry House,
Dean Ryle Street,
S.W.1.

VT

SECRET

Mr. Garrard Ministry of Aviation

[redacted]

[redacted] I find that I have not [redacted] for your note of 21st April Mr. [redacted], who initiated this correspondence was, I believe, now left the [redacted] Industries; so I have not sent replies to the letters at the end of your note. Before he left I sent him a note of 14th April, of which I enclose a copy.

...

[redacted] I would be well worth publishing an agreement from the Secretary of State on the value of machining steel: could you do this? I take it that your "Cooling" comments [redacted] I did not intend to be clever in any technical sense, but the person in charge would refer to [redacted] - which [redacted] - just to put him in position while the concrete is poured. [redacted] would sometimes, especially in proprietary [redacted].

...

Just for your information, I enclose copies of correspondence between Mr. [redacted], [redacted] and myself.

24th March 1966.

F.A. Harry

[redacted]

22.6.66

J.C. Garrard, Esq.
Ministry of Aviation
[redacted] (Effects)
Room 508
Prospect House
80 New Oxford Street
LONDON W.C.1

(Copies to W+M.B. and to Comm. B.)

[illegible] Visiting [illegible] wives

[illegible] Margaret [illegible]

I [illegible] my thoughts and papers on the subject and find that I do not [illegible] have sent you copies of a talk giving my [illegible] of [illegible] at the [illegible] of the Legislature with the stenographic references

I signed the minutes and retain 2 copies of the record, which you may wish to [illegible] Mott & Whitcher

F. H. Perry

Secretary, Children's Bureau

Home Office

June 15th '66

Ministry of Aviation Memorandum

FROM : (Branch and Address) AWD 2 Effects

Telephone No. Extn. 2092

Our ref. : XY 306/04.

TO : F. V. Pavry Esq
Scientific Advisers Branch
Home Office, Horseferry House

8. 6. 1966.

Your ref.

Dear Frank E.M.P. M125/DASA/1,

Very many thanks for the sight of the CD16249 attached note by Don Smith of Dasa. I have taken numerous (4 total) copies, as it is excellently declassified - the first time the magnetic field has been stated below Secret. Atomic. I am L.H.IR discussing this with AWRE. Use the reverse for continuation or reply as necessary.

Re may have got away with it by omitting time statements. Do you think I ought to attend this working party? I'm not clear on its terms of reference.

Yours

Dennis

See Garrard's note on classification. He is obviously interested that this has been officially down-graded by DASA. This report - "Effects of the Electromagnetic Pulse" - was obtained by Mr. Stanbury at the May 1966 meeting of the NATO Scientific Working Party)

F. H. Pavry

17th June, 1966

M^r Law.

[illegible]

I enclose a copy of some extracts
by Garrard in his recent notes.
N I C [illegible]
[illegible]
may be worth making.

F Flowry

S.A.B. April 25th '66

P.S. If we suggested a [illegible] of [illegible]
Further Alternative would be to ask
if the Warning & Monitoring Network, it
might be a will to [illegible] has sent
[illegible] isolators, or ask Garrard to do so, in
that particular content

Tel. No.: Museum 3644
Extn.. 2092
Your Ref. .....
Any communication on the subject of this letter should be addressed to:
THE SECRETARY
and the following reference quoted:
XY/222/05

A.W.R.E. (Aldermaston)
Room 508,
Prospect House,
80-110 New Oxford Street,
London, W.C.1.

21st April, 1966.

Mr. Pavry,
Scientific Adviser's Department,
Home Office,
Horseferry House,
Horseferry Road,
London, S.W.1.

Dear Frank,

E.M.P. Screening

I have never been quite happy about the U.S. claims that "re-bars" provide substantial shielding as I have always suspected, perhaps quite unjustly, that they were commercial attempts to whitewash the omission of any special measures from a particular class of early U.S. installation.

On general grounds it is to be expected that a well-conducting mesh will be an effective electrical screen at wavelengths large compared with the mesh spacing, at distances back from the mesh of at least a few times the mesh size so that the fringing field penetration is slight. I am not at all sure whether a practical reinforcing bar system, with pretty haphazard electrical contacts and relatively high resistance material (it's the electrical skin depth of a fraction of a millimetre not the actual bar size that matters) can really be considered as any approximation to the ideal conducting mesh.

As regards the magnetic screening I am really quite sceptical, as the effective permeability of such a system at 20 Kc's or so must be pretty small. In fact some years ago Abercrombie and I had a good loud laugh at a U.S./U.K. presentation on the subject, and the two sides agreed to differ, we not being involved at the time, and the U.S. speaker being a Contractor's man whom we did not expect to admit shortcomings.

If this is a live issue, I should suggest we contact the Electrical Research Association people who have published some highly regarded work on the subject. They would be able to advise as to the likelihood of our getting appreciable screening with or without bonding. My guess, and it is no more, is that 10-20 db might be obtained in either case, but that other than by chance no more could be relied upon in view of the number of wires and metal pipes running into the structure in actual practice.

I seem to remember M.P.B.W. saying that bonding for some work was normal practice, but the context now escapes me.

As regards simulators, Mr. Low may care to consider the following points:- (in the context of an on-site test with a ...

(a) What do you want to simulate and on what installation?

(b) Are you prepared to instrument your installation and interpret the results (or make arrangements for this to be done)?

(c) How big a financial outlay are you prepared to incur?

Yours ever,

D.J. GARRARD.

2 carbon copies.

Reference CDA 36/18/2

Mr. Pavry

Electro-Magnetic Pulse

Thank you for your note.

As regards simulators, I am not sure whether you are aware that A.W.R.E. have under development a high-power discharge apparatus for use as a signal source to test equipment which they are producing for us to detect nuclear explosions. The apparatus has been designed primarily as a radio frequency source for field testing of direction-finding equipment, and the hope is that it can be mounted in mobile form. I do not know whether it would be suitable for the investigation of other induction and shielding problems, but the possibility may be worth looking into.

13th April, 1966.

Warning and Monitoring Branch

Mr. Garrard

... I enclose a copy of a note from Mr. Law, of our Warning and Monitoring Branch, and a copy of the reply I have sent him.

Could I have your comments, preferably with a spare copy to send Mr. Law?

... I am returning Sunde's paper. Many thanks for letting us see it.

F.H.

5th April, 1966.

Home Office
Scientific Adviser's Branch
Horseferry House
Dean Ryle Street S.W.1

Mr. Law
Warning and Monitoring Branch

Replying to your note of the 1st, I think it is true to say in any box-type structure in reinforced concrete the reinforcing bars are likely to be bonded all round. They are commonly held to each other with binding wire, to keep them in place and this should, I imagine, be enough to give the necessary electrical connection. In certain jobs spot-welded steel meshes are used for reinforcement, and this would presumably be better still, especially if good contact between horizontal and vertical meshes were taken care of. My impression is that it would be a good thing to draw the attention of M.E.W. to the advantages of a continuously-conducting cage of reinforcement. However, it would be worth asking Garrard what he thinks; I will do this, and let you know what he says.

I will also ask him about simulators. I had the impression that this was something A.W.R.E. would be bound to develop.

F.A.P.

5th April, 1966.

Scientific Adviser's Branch

EW

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CDA 36/18/2
59

Mr. Parry

Electro-magnetic pulse

Thank you for your note of 25th March; I am returning the report by Sunde and your minute to Mr. Brooker.

Am I right in thinking that Sunde's paper suggests that the reinforcing bars of ferro-concrete buildings can give worthwhile magnetic and electric shielding, but only if they are bonded together to form conducting loops enclosing the volume to be shielded? I do not know if this would be normal civil engineering practice, but it seems doubtful. Would it be worth suggesting to Ministry of Public Building and Works that such bonding should be required in new civil defence construction?

As regards the "Basic-principles" note, I should be grateful if you could confirm that there is no prospect of simulators becoming available in this country (item 21 refers).

1st April, 1966.

Warning and Monitoring Branch

Mr. Law
Warning and Monitoring Branch

Electro-magnetic Pulse

You may care to see the attached report by Gunde, before I return it to Garrard: also the list attached. I enclose a copy of the note I sent with them to Brooker.

As you will see, he suggests we convey the American list of "Basic Principles E.M.P. Protection" to N.A.T.O. I think you have had dealings with N.P.A.A. on this subject, so would you convey the list, explaining that it came to us by a rather round-about route?

F. H. PAVRY
25 March, 1966

Scientific Adviser's Branch

Mr. Low

[redacted]

[redacted]

You may care to see the attached report by [redacted], before I return it to [redacted] also the first attached. I enclose a copy of the note I sent with them to Brocker.

As you will see, he suggests we convey the American list of [redacted] principles [redacted] protection' to M.E.I.S.. I think you have had dealings with [redacted] on this subject, so would you convey the list, explaining that it came to us by a rather round-about route?

[redacted]

Scientific Adviser's Branch

7C[A]

M' Brooker Communications Branch.

DGAW 332/65 -65/1

I enclose a paper on 'Switching Centre Shielding Against Atmospheric Induction' by E D Sunde, of Bell Telephones, with an Amendment added.

These papers were given personally to M' Garrard by the author, and they have been lent to us for information. (I gather that Sunde is the author of a standard work on effects of lightning & protection.)

You may care to see these papers, and let the GPO people concerned see them. They could be copied if required, though Garrard suggests it might be as well to put something like Restricted, or Official Use Only, on any copies made.

As these* are, I think, the only copies available in this country, will you please ensure that they do not go astray?

F.H.Lavery
5 A.B
March 2nd '66

P5./PTO

* DGAW 332/65 and DGAW 332/65/1

P.S. I also enclose a sheet entitled "Basic Principles E.M.P Protection", which you may be interested to see, and discuss with the G.P.O.
This piece of paper is of American origin, and was made available to me by the Dutch delegation at a Nato meeting.
Some of the principles may be counsels of perfection, but I imagine that it will be of interest to have a statement of this kind.
We do not want this sheet returned.

Ful.

Ful 25/3
M Savory Thank you.
Doc has these copied and sent one to GPO (Ford) — marked restricted for official use only. I am returning the single sheet for much is of practical interest to MPBW and I wonder whether you can get it into Headoffice.
M Buxton
16.3.66

Mr. J. D. Milborrow
Ministry of Power

I enclose 2 copies of "Basic Principles E.M.P. Protection". This list of principles is of American origin, and was obtained through a Note Warning.

It should be of interest in connection with the protection of electrical power supplies.

F. H. PERRY
25th March, 1966

Home Office
Scientific Adviser's Branch
Horseferry House
Dean Ryle Street
LONDON S.W.1

Mr. J. S. Milborrow
Ministry of Power

I enclose 2 copies of "Basic Principles L.M.P. Protection". This list of principles is of American origin, and was obtained through a Delta meeting.

It should be of interest in connection with the protection of electrical power supplies.

F. H. PAVRY
25th March, 1966

Home Office
Scientific Adviser's Branch
Horseferry House
Dean Ryle Street
LONDON S.W.1

Registry Pl. file Fol

Mr Pavry

I spoke to Mr Cambrook, and agreed that we would try to include A.I. in future, in meetings or in the circulation of reports on E.M.P.

F. H Pavry 31/3/66

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Mr Cambrook x672 Yang

would you please have a word with him - He (AIDiv) feels that an AI Div representative should have attended & should be invited to attend all meetings about E.M.P.

Explained to Mr C. that all the right people were, in fact, invited. and that I had a difficult time getting co-operation. Fol. 1/4

S.S.J.
30.3.66

.....

I certify that, on each occasion for which day subsistence allowance is claimed, I necessarily spent more on meals than if I had been at my permanent station.

.....

.....

certify that, on each occasion for which day subsistence allowance is claimed, I necessarily spent more on meals than if I had been at my permanent station

....

I certify that, on each occasion for which day subsistence allowance is claimed, I necessarily spent more on meals than if I had been at my permanent station.

.....

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HOME OFFICE

Horseferry House, Dean Ryle Street, LONDON S.W.1

Telephone: VICtoria 6655, *ext.* 47

Please address any reply to
THE UNDER SECRETARY
OF STATE
quoting:
Your reference:

Mr Stanbury,
C.S.A.

* Material I obtained from Garrard and from Nato ad hoc Group, and sent to Brooker for hui o G.P.O.

F. Mawby 23/3

P. Crocker Communications Branch

[redacted] a paper on Earthing Centre Shielding Against Atmospheric Induction by E.D. Sunde of Bell Telephones with an Amendment added

These papers were given personally to Mr Garrard by the author and they have been sent to us for information. (It is felt that Sunde is the source of a standard [redacted] on earthing & protection)

If we may have to see these papers, and let the G.P.O people concerned see them. They could be copied if required, with Garrard's agreement (might be as well to put caution) [redacted] Head like to keep any copies made.

For this we shall keep any copies until the matter is finished & then when that they do not go astray.

[redacted] SA[redacted]

PS/[redacted]2

*DGAW 332/65 and DGAW 332/65/1

PS I also enclose a sheet entitled 'Basic Principles EMP Protection' which you may be interested to see, and discuss with the G.P.O.

This piece of paper is of American origin and was made available to me by the Dutch delegation at a Nato meeting.

Some of the principles may be commonsense perfection but I imagine that it will be of interest to have a statement of this kind.

We do not want this sheet returned

Ted

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Ministry of Aviation Memorandum

18 Feb 1966.

FROM : (Branch and Address)
AWD2 Effects

TO :
FV Perry Esq
Scientific Adviser's Staff
Home Office

Telephone No. Extn. 1369.

Our ref.. XY/396/04

Your ref. :

EM Flash.

I herewith the original of the report we discussed. Return of the copy would, as we said, be appreciated. CD16148 CC67/AC/158-WP/11 CD16142 I also enclose on loan for your information two parts of a report from Sandia

L.H.1R M737 82 Gp BIS

Use the reverse for continuation or reply as necessary.

of Bell Labs that I was given in USA.
It is unclassified and extends the term
quite - but beyond the old BLAIRA
letter of 1959. vide (2).

Yours sincerely

Ed DGAW 332/65
S32/65/1.

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Ministry of Aviation Memorandum

FROM : (Branch and Address)

TO :

Telephone No.

Extn.

Our ref.

Your ref. :

These Rules came as a loose sheet of paper tucked into a Dutch report to the Nato ad hoc Group CD(60)97. They are clearly of US origin, & the Dutch confirmed this at Group Meeting Feb '66

Use the reverse for continuation or reply as necessary.

Basic-principles E.M.P. protection

1. Lightning Protection for all power cables; power supply as much as possible by a power station within the hardened facility
2. Put wires in boxed, grounded circuits
3. Use ground-screen over air-conditioning outlets. Ground all ducts
4. Ground rebar especially if tack-welded
5. Install largest available lightning arresters on power-system transformators
6. Install spark gaps on telephone lines
7. Ground cable outer-shields
8. Ensure that signal cable shields are well grounded at point of entry
9. Bury cable as deeply as economically feasible
10. Connect the water pipes and other metallic entries into the grounding system
11. Install lightning arresters on antennas and input leads which cannot be directly grounded
12. Educate personnel in protection practices
13. Adopt protection procedures to particular areas
14. Do not interrupt shielding provided by outer conductor when a lead is tied to coaxial cable
15. Ground all non-essential equipment
16. Caution natural grounds are often unsatisfactory use massive counter poise at each site
17. Ensure that entire conduit system is well grounded
18. Avoid use nonconducting lubricants when assembling conduit pipes
19. Ensure that electrical contact exists between conduit and terminal box
20. Install grounding strap from terminal box to door at box
21. Specify EM-testing of the completed installation with appropriate simulation devices to ensure adequate protection
22. Use dry rather than oilfilled transformators
23. Provide surge protection for emergency power equipment

4. [illegible] lightning protection on all above ground lines:

[illegible]. If power equipment supplies several sites, install lower value fuse [illegible] the equipment end

[illegible]. Use fuses rather than circuit breakers ← Garland then privacy' [illegible]

7. Do not use slow-blow or delay fuses

[illegible]. Design fuses within safety margin

[illegible]. Provide automatic closing doors with recessed fits for shielded rooms

[illegible]. [illegible] dehumidified storage for materials to be used in dehumidified areas

[illegible] poor electrical contact points between screened areas by applying [illegible] across the areas

32. Put single-phase protection on all three phase equipment

33. Ensure that the intrasystem wiring conforms to a "tree" or radial wiring scheme

Copies went to:- Brooker, G.P.O. (see doc. 65)
WHWMO ?
MPBW
M of Power } See D.O. sheet CD 16171

CONFIDENTIAL

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L.H. 13E

Telegrams: Avmin, London, Telex.
Telex No.: 22241.
Telephone: Museum 3644.

Extn. 1369

Your Reference

Our Reference XY/306/04

MINISTRY OF AVIATION,
A.W.D.2(EFFECTS),
Room 846,
ST. GILES COURT,
1-13 ST. GILES HIGH STREET,
LONDON, W.C.2.

3rd February, 1966.

Dear Frank

Advisory Bureau Corps of Engineers Report No. 129

First let me say how much I appreciate your letting me have a sight of this report, and of the previous paper AC/158-WP/11. Report No.129, which I return herewith is, quite frankly, of relatively little interest to me because we have already known for a considerable time about the Kompaneets paper and its rebuttal by Gillinsky of Rand Corporation. I am not in a position to go through the German analysis in detail, and so cannot comment on its validity. I do however note Figure 2 on page 5 as being more or less in accord with Figure 1 of the Secret paper. This in fact does no more than increase my suspicion that both are derived from the same source. This you will recall is AFWL, who made a presentation at the Paris seminar at which we were both present, and which the German paper mentioned. The principle value of the German paper is therefore in its presenting a small proportion of the data at a lower security grading. I should have thought that this was of relatively little significance to the U.K., and indeed may well be irregular. *

On the other hand, NATO Secret working paper AC/158-WP/11 is a most valuable document. I have already shown a copy of this to R.A.E., who said that it would probably cover their immediate requirement for data for first phase analysis. I am taking steps to show another copy to R.R.E. Malvern, and will also discuss it with A.W.R.E. next time I am there. I hope to make further comments following these discussions, but in view of the current pressure of work it is just possible that I may not be able to do this before the date of your meeting.

In case I do not manage to make a formal comment, I should like to mention here that the most useful extension of this document would be in the direction to facilitate estimates of the actual voltages and currents to be expected in conductors near the surface or at various depths underground. I am all too well aware that this document, in providing very valuable data as to the peak values of the E.& H. fields, leaves a considerable amount of work to be done in its application to any particular problem.

Yours ever

David

D. J. GARRARD

F. H. Pavry Esq.,
Scientific Advisor,
Home Office,
Horseferry Road,
S.W.1.

* Symposium Record Vol 2 p 2> Refers and is Nato Secret the same applies to page 33 ibid.

CONFIDENTIAL

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Mr Stanbury to see.

F.M.
3/2

CONFIDENTIAL

Mr. Sargeaunt

Electro-magnetic Pulse

Thank you for your minute SAC/62 10/156/2 dated 28th January 1966. It is certainly some comfort to know that the vulnerability of electrical and electronic equipment to nuclear radiation and electro-magnetic flash has been studied by the Nuclear Weapons Lethality Committee. I cannot however draw much consolation from the conclusion in their report quoted in your minute. It is only a statement of a fact - and not very comforting fact at that. I hope and assume the report will include a strong recommendation that a greatly increased effort be devoted to Britain's part which well prove to be a disastrous gap in our existing knowledge either nationally or in co-operation with the Americans and/or other allies.

31st January, 1966

CONFIDENTIAL

SAN/62 10/156/2
SAN 19/7/1 60

Sir Walter Merton
Mr. Firth
Mr. Gelly
Mr. Elgood

Electro-Magnetic Pulse

As you know, we have tried to keep abreast of progress in the study of the effects of EMP on communications, and concern has sometimes been expressed at the lack of definite information which can be applied to Civil Defence planning.

We have been aware all along that such information is of great importance to all the Services, and that a concentrated research programme has been in progress. It has been clear, nevertheless, that this is an extremely difficult problem, the difficulty being aggravated by the ban on test explosions. The American Defense Department is fully aware of the need for information, and the main research effort is in the USA. British experts are in touch with the American team, and it is hoped that we will eventually obtain a Handbook containing the kind of guidance we need. But it cannot be expected that this will be available in less than a year or two.

Meanwhile, it is understood that the GPO are in touch with experts at Aldermaston on certain specific problems.

You may care to know that EMP has received continuous attention from the Nuclear Weapons Lethality Committee. This Committee has the Director General of Atomic Weapons of the Ministry of Aviation as Chairman, and all Service Departments, as well as the Home Office, are represented.

The Committee has recently prepared a "Survey of Current Knowledge of Nuclear Weapon Effects, and of the Adequacy of the UK Effort in this Field". The Survey has been sent to all the Chief Scientists of the Service Departments.

As you will see, from the first conclusion of the Survey, which I quote below, there is a consensus of opinion regarding the importance of the subject of EMP:

> "A very considerable gap exists in our knowledge of the vulnerability of electrical and electronic equipment to nuclear radiation and electromagnetic flash. This knowledge is essential to the study of many systems and complex targets. The effort currently devoted to these investigations is insufficient to obtain this information in a reasonable time".

ASCAUNT

Chief Scientific Adviser

28th January, 1960.

Telegrams Avmin, London, Telex
Telex No. 22241
Tel No. Museum 3644
Extn.

Your Ref

Any communication on the subject of this letter should be addressed to
THE SECRETARY
and the following reference quoted :
F306/64

MINISTRY OF AVIATION,
ST. GILES COURT,
1-13 ST. GILES HIGH STREET,
LONDON, W.C.2.

members

Effects [illegible]

E.M.P. Workshop at Santa Barbara
[illegible]-30th June, 1965

Mr. S.D. Abercrombie and Dr. E.[illegible] Prescott [illegible] and Mr. D.J. Garrard of Ministry of Aviation were invited by D.A.S.A. to participate in this project. The idea was to get together those people directly concerned in the determination of the electromagnetic flash signal from nuclear explosions and in the evaluation of its interaction with systems, with a view to writing a comprehensive document as a basis for future design. It was felt that the present moment was opportune because the cessation of atmospheric testing has meant that little more information is to be expected in the foreseeable future, and because the large theoretical effort which has been put into this study is about to be diverted on to other problems.

A group of about 30 people therefore met at D.A.S.A. invitation at the I.T.T.C.A. Data Centre G.E. Tempo, Santa Barbara, California from the [illegible]th to the 29th June, 1965. After a brief introductory talk the party divided into four sections each charged with writing one chapter of the proposed manual. These dealt with:

1. Basic phenomena.
2. Electro-dynamic [illegible] EM field calculations.
3. EMP induction into systems.
4. Experimental techniques.

Details of the chapters and the author responsible for each [illegible]

The tentative schedule for [illegible] the EMP handbook [illegible] to be ready for publication by October of this year. It is not intended that the invited participants, [illegible] would incur [illegible] effort [illegible] and would be [illegible] important [illegible] would [illegible] people [illegible] to be arranged to [illegible] their [illegible] with [illegible] other [illegible] will have to be [illegible] with [illegible] proceedings.

[illegible] the handbook, but period [illegible] in this connection and it would [illegible] publication of such a document. It [illegible] document unless we ask for it, as shown by the fact that [illegible] participants in last year's EMP conference at Boston have not [illegible] the proceedings at the same time as U.S. participants.

It is intended [illegible] dealing with [illegible] laboratories under [illegible], and from my attendance at the I.E.E.E. symposium at the University of [illegible] Radiation effects on Electronic components be written shortly.

[illegible]

[illegible] Effects,
[illegible]

[illegible] RARD.

[illegible]

[illegible] SUMMARY

Chapter 1. [illegible] Currents and Conductivity (Malik

I. [illegible]

1. [illegible]
2. Air/Ground
3. Fission Products

II. Gamma Ray Transport (Schaefer)

1. Scattering
2. Source Geometry
    a. Isotropic
    b. Point
    c. Shell

III. Air Chemistry (D[illegible]

1. Conductivity
    a. [illegible]
    b. [illegible]
2. Charged Particle Density
    a. Lumped parameter
    b. Individual reaction
3. Mobility
    a. Field dep.
    b. [illegible] dep.

IV. Recommendations for Future [illegible]

1. Underground
    a. [illegible]
    b. [illegible]
    c. [illegible] neutrons
2. Interpretation of Monte Carlo
3. Air Chemistry

V. References

Chapter 2. Electrodynamics - [illegible] Field Calculations [illegible]

I. [illegible]

II. [illegible] Symmetric [illegible]

1. Radial E. Field
2. [illegible] yield

III. Asymmetri

1. N[illegible] (Longmire

a. [illegible] (Longmire

b. [illegible]

c. [illegible] (Longmire

IV. [illegible] Air Asymmetry (Suyder

V. Free Air Burst, [illegible]gnetic Effect (Karzas)

VI. X-Ray Effect (Karzas

VII. M H D Effects (Reinheimer, Dracott, Whitmer and Tyle

VIII. References

Chapter 3. EMP Induced into Systems (Draper

I. Fields [illegible] Ground (Longmire

II. Electrical Properties of the Ground (Scott, et al.

III. Cables: Types, [illegible]racteristics, Terminations (all

IV. [illegible] of Calculating Induced Cable Current

1. Longmire (Mo

2. [illegible], Vance

3. [illegible] (Draper, Morton

V. Mutual [illegible] Coupling Measurement

VI. Computer Systems [illegible]

VII. Direct Permanent X Ray Effect (Longmire

VIII. Recommendations for Future Design (all

IX. Recommendations for Future [illegible] All

X. References

Chapter 4. Experimental Techniques [illegible]

I. Non Nuclear Simulation

1. Transmission Simulation

a. Nuclear requirements, facilities and equipment

b. [illegible] (Longmire, Morton, Abercrombie

2. Environmental Simulators (Barrard, Abercrombie, [illegible]

a. System exposure requirements

b. Energy sources

c. Free field sources

II. Nuclear Simulators (Masters

1. Introduction, Unique Features, Atomic Burst, Confinement and consequence, Implications for Simulation

(References [illegible]

III. Alternatives

1. Nuke Bombs (Henderson
2. Lack of Possibilities (Winters
3. Large Cavity (Smith)
4. Acceptance of Confinement Devs of exposure requirements

IV. Reference .

Mr Sargeaunt

Notes of meeting addressed by Derek Garrard on Electro-Magnetic Pulses (23rd August 1965)

1. Mr. Garrard said that the frequency of such pulses was so low that unless equipment was connected to very long cables the question of massive damage over a very wide area was extremely doubtful.

2. The problem of damage due to lightning was mentioned and the fact that the G.P.O. had long since given up using lightning traps. It would be possible to use self adjusting gas ionisation traps, but the G.P.Os attitude was that this was a defence charge which should not be put on to the normal commercial installations.

3. Mr. Garrard suggested that Home Office installations should be tested with a pulse generator, as the greatest chance of damage was at the equipment end.

4. There was no danger of ordinary transistor sets being put out of action by an electro-magnetic pulse from a bursting nuclear weapon, but there was a danger to old steam radios connected with long aerial connections or Earth connections.

5. There was very little information available about the electro-magnetic pulse from a nuclear burst above about 50km i.e. above the atmosphere. Much of this pulse received at ground level is within a microsecond and comes from the beta emission at the point of the explosion, and not predominantly as was originally believed, from the electrons resulting from collision by the X-ray photons as they entered the atmosphere.

D W Gladwyn

23rd August, 1965.

19/7/1

Mr. Paramount

Neutro-negatic Pulse

[redacted] to attend, in [redacted], Dr. Mowbray and me.

Mr. Parry
Lab. August 1956.

[redacted]

(Copies sent to Mr. [redacted], Dr. Brooker, Mr. Colly).

Mr. Pavrøy,
Scientific Advisers' Branch

Electro-magnetic Pulse

With reference to your minute of 29th July, 1965, to Mr. Brooker, Communications Branch, the Inspector General has expressed a wish to attend the proposed meeting. He is able to attend on 23rd August, but has asked that the meeting be put back to 1045 hours. If this date and time are not convenient I would be glad if you would let me know as soon as possible of any alternatives so that the Inspector General may be informed.

The Warning and Monitoring Branch would wish to be represented.

G. A. POTTER.
3rd August, 1965.

Warning and Monitoring Branch.

M' Sargeaunt. I spoke to you about this. Filing 55
M' Stanbury to see

Mr. Brooker
Communications Branch

Electro-magnetic Pulse

You asked me on the 20th whether we have had any further information on the progress of research in this field.

As I said, I have seen references in the minutes of a Ministry of Aviation Committee meeting, to the effect that work on the American Handbook for the use of engineers proceeds. In addition, it seems, the American authorities now have simulators, which can be used to test existing circuits, etc.

I have telephoned Mr. Garrard, as I knew that he has just returned from discussions with the Americans, and rather that he was collaborating in the drafting of the Handbook. It seems that this is to be a full-sized book, and it would be unrealistic to expect that copies will be available here sooner than about the end of next year, at the earliest.

I therefore asked Mr. Garrard if he would be willing to tell us, at an informal meeting, what he can of the present position. He agreed to do this, but as he has been away for the last month he asked me to give him a few weeks in which to sort his papers and data, and fulfil other commitments.

I doubt if we want to make this a very large meeting, on the lines of the 'Seminar' last October, but there are certain people we ought to invite to keep them informed. If you agree that such a meeting would be useful to you, perhaps you will give me an indication of whom you think we should invite.

/Mr. Garrard

Mr. Garrard indicated that he should be available during the last week in August. So it might be as well to start thinking about a suitable date. Say Monday, August 23rd, 10.30 a.m.?

F.H. PAVRY
29th July, 1965.

Scientific Adviser's
Branch.

(Copies to Mr Garrard
Mr Gelly)

Mr Law

Many Thanks Law

E.M. Pulse.

This is the paper Mr Stanbury mentioned a day or so ago, as giving examples of effects.

This is quite an old paper — we got it in 1962 — and copies went to Comms. Branch, G.P.O. & Ministry of Power.

Although a copy was not sent to you by us, the assumption was that you would be advised by Comms. of any implications in the report.

Mr Garrard's graphs etc. at the 'Seminar' on Oct. 20th 1964 were based on these, and more recent, data.

P.S. P.T.O.

F. Mavrey May 27th '65.

I also enclose for your information a copy of the recent AWICE report by F.L. Hill, which Mr Stanbury mentioned.

SAN/62 19/7/1

Mr. K. W. Clark
A.2 Division

I have consulted the Ministry of Aviation on the question of security raised in your minute of March 29th/ on file CDP/64 361/42/1

You could give the following information to Local Authorities, without the need for any security restriction:-

> Recent research indicates that the electromagnetic effects of a nuclear explosion can give rise to induced currents in electrical circuits, such as those used for light and power. These currents may be of sufficient magnitude to cause electrical damage beyond the range of serious blast damage. (It is therefore considered advisable to hold spare fuses, etc.)

I think this is the kind of explanation you need?

F. M. Lavery

5th April 1965.

Scientific Adviser's
Branch.

(Copy sent to Mr. D. J. Garrard.
A... lans, Ministry of Aviation)

[redacted]

[redacted] report to the Inspector [redacted] taken to counter the [redacted] flash, and I should be [redacted] let me know what progress has [redacted] referred to in the Inspector [redacted] 20th November

[redacted]

[redacted]

[redacted] and Monitoring Branch

50

MINIST[illegible]
PUBLIC BUILDING AND WORKS
Cleland House, Page Street, LONDON S.W.1
Telegrams: Travaucle London S.W.1
Telephone: Reliance 7611, *ext.* 1388

Our reference: AH/981/1
[illegible]

49

[illegible]

[illegible] 196[illegible]

Dear [illegible],

[illegible] 5th, [illegible] the [illegible] effects of [illegible] on [illegible] the [illegible] installations [illegible] provide [illegible] control [illegible] Control [illegible] system.

[illegible] general, [illegible] P.O. [illegible]

[illegible] existing [illegible] electromagnetic [illegible] effect on [illegible] circuitry. Protection against this effect as far as communications are concerned will be for the G.P.O. and our Communications Branch to pursue while protection of the power supply will be a matter for the Electricity authorities. The question remains, however, [illegible] in particular [illegible] [illegible] meeting on this subject [illegible] in a position to [illegible] possible [illegible] may be necessary.

[illegible] Yours sincerely

(Sgd) P.V. COLLYER

CDA/59 36/18/2 (copied from).

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CONFIDENTIAL

Director of Communications

I refer to my minute CDA/59. 36/18/2 dated 21st October 1964.

I should be grateful, if when replying, you would consider the whole range of communication (land line and radio) and radio equipment used in Civil Defence which may be equally susceptible to damage.

I am sending a copy of this minute, together with a copy of my original minute of 21st October 1964, to both Mr. James and Mr. Jones.

W. H. MERTON

20th November, 1964

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THE QUEEN'S UNIVERSITY OF BELFAST

PROFESSOR K. G. EMELEUS
TELEPHONE: BELFAST 30111

DEPARTMENT OF PHYSICS,
QUEEN'S UNIVERSITY,
BELFAST 7,
NORTHERN IRELAND

2 December, 1964.

F. H. Pavry, Esq.,
Scientific Advisers' Branch,
Home Office,
Horseferry House,
Dean Ryle Street,
London, S.W.1.

[redacted]

Dear Mr. Pavry,

Thank you for your letter of December 1 and the enclosure, which I am very interested to see. Its classification has been noted.

Yours sincerely,

K.G. Emeleus.

K.G. Emeleus.

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Covering SECRET

531

1st December, 1964.

Dear Professor Emeleus,

We recently arranged a meeting with the Ministry of Aviation on electro-magnetic effects. Since you were asking for information on this subject earlier in the year, I thought you would be interested to have a copy of the minutes.

Yours sincerely,

F. H. Perry

Professor K. G. Emeleus, M.A., Ph.D., Sc.D., M.R.I.A.
Dept. of Physics
Queen's University
Belfast
N.I.

CONFIDENTIAL

45

CDA
59 36/18/2

9 November, 1964.

Dear Batho,

Electro-magnetic effects of nuclear weapons

A meeting was recently held under the aegis of our Scientific Adviser at which experts from the Ministry of Aviation described briefly the nature of the short but intense electro-magnetic disturbance accompanying a nuclear explosion. It appears that very large voltages and currents may be induced in electrically conducting materials at considerable distances from the explosion, and the Post Office and the Ministry of Power are, I gather, looking into the implications for home defence plans of the likely effects on communications networks and power distribution systems.

For the Warning and Monitoring Organisation I am anxious to find out whether these electro-magnetic effects constitute a hazard additional to those of blast and heat and radioactive fall-out which we have tried to take into account in planning our buildings. For example, is it possible that voltages induced into internal power wiring could break down the insulation of the wiring and cause such a surge of current, from the supply mains at the local generator, that the power supplies would be disrupted? If such results [illegible], would they occur at ranges at which the buildings might be expected to survive the blast from the explosion? If so, what steps could be taken to counter, or minimise, the danger? I am

/are

W. J. S. Batho Esq.
Ministry of Public Building and Works (A.S.123)
Cleland House
London S.W.1

CONFIDENTIAL

[redacted]

are some questions which occur to me, and there may well be others which ought to be asked and answered in relation to our Sector Operations Centres and the Royal Observer Corps Group Headquarters, if we are to make proper plans to survive a nuclear attack.

From what was said at the recent meeting it seemed to me that answers to such questions could best be obtained by [redacted]g in detail the electrical systems within the [redacted] in the light of the knowledge of the electro-magne[redacted]ich the Ministry of Aviation is prepared to make available to those who need to know. Perhaps such eq[redacted] have already been made in relation to buildin[redacted]s of the ty[redacted] with which we are concerned, and you can let me know the sort of results we could expect. If not, I should be very grateful if your experts could look at the problem for us.

Yours sincerely,

[redacted]

[redacted]

CONFIDENTIAL

M. Oattis

GPO

Inland Telecommunications
Department
Headquarters Building
St. Martin's-le-Grand
LONDON EC1

Telex: 21166 (GOHQ LDN)
Telegrams: Central London EC1
Telephone (Headquarters) 4[illegible]

In any reply please quote:
Your reference: CLA 36/18/2

26 October [illegible]

Flash Effects

Thank you for your letter of the 22nd October, in which you seek confirmation that the Warning and Monitor- Branch will be told in due course about the result tudy of flash effects to be made by AWRE. My is that the Ministry of Defence, prol , will report en complet ub-Committee of the Com.ine. ittee, on which, of course, the Home Office i presented by Elgood. I assume that this is th through which Warning and Monitoring Branch would be told munication equipment.

ting on the 20th October, th on the basis that it will mation supplied by the Defence regarding communi ant con n.

CONFIDENTIAL

which I have
lity of mention-
con:i
upon these instruments, and I will let you
some of the

Yours sincerely,

CONFIDENTIAL

CDA 36/18/2

22 October, 1964.

CONFIDENTIAL

Dear Ford,

Electromagnetic, etc. effects of Nuclear Explosions

From the discussion of the above mentioned subject at the meeting on 20th October I understand that the Post Office will be considering the problem of the electromagnetic and other effects as they concern telephone and line communications generally. No doubt we in the Warning and Monitoring Branch will be made aware of your conclusions, in due course.

Meanwhile, I wonder if I could ask you to have a look also at the Royal Observer Corps teletalk instrument and the carrier equipment, both of which contain [illegible] and ought I suppose to be considered in relation to [illegible] as well as electromagnetic flash. We should, of course, very much like to know whether these items of equipment are likely to be susceptible to damage from these effects, and if so what, if anything, could be done to protect them.

Yours sincerely,

K. Ford Esq.
General Post Office
Inland Telecommunications Department
St. Martin's le Grand
LONDON E.C.2

Confidential

[illegible] of Communications

At the meeting held on 20th October to [illegible] electrical and electronic equipment, I formed [illegible] affected. I assume thereof [illegible] be closely associated with [illegible] which the Post Office are to [illegible] at an early date.

[illegible] ...ld radiation [illegible] electromagnetic [illegible].

[illegible] grateful if [illegible] one can [illegible]

:on to safeguard this a[illegible]
[illegible].
:rifications for new equipment the
environment under which they will be
to function.

W. H. MERTON

[illegible]

SECRET

XY/306/01

Minutes of a Meeting held in Room 208, Horseferry House, Dean Ryle Street, S.W.1, at 10.30 a.m. on 20th October, 1964.

Present		Representing
Mr. H.A. Sargeaunt	In the Chair	Sc. Adv., Home Office.
Mr. J. Brooker		Home Office, Comm. Branch
Mr. R.E. Glaysher		" "
Mr. N. Morley		" "
Mr. R. Watson		" "
Mr. R. Firth		" "G" Divn.
Mr. J. Miles		" S.A.B.
Mr. F.H. Savry		" "
Mr. G.R. Stanbury		" "
Mr. E. Leader-Williams		" "
Mr. N.F. Law		" Varn. & Non. Branch
Mr. J. Gelly		" " " "
Mr. G. Potter		" " " "
Sir W.H. Merton		Insp.Gen. of C.D.
Mr. C.E.C. Hurst		Ministry of Public Buildings and Works
Mr. C.W. Mott		C.E.G.B./W. .
Mr. E.J. Whitcher		London Elec. Board.
Mr. T. Kilvington		G.P.O./T.D.
Mr. K. Ford		G.P.O./I.T.D. TB.
Mr. R.H. Franklin		G.P.O./T.D. L.M.O.
Col. T.W. Armour		A.W.R.E.
Gp.Capt. P.M. Chettle		M.O.A. A.D./A.W.D.2.
Mr. D.J. Garrard		" A.W.D.2 (Effects)
Mr. T.S. Popham		M.O.D./Ord. Board
Mrs. M.I. Wilkie	Secretary	M.O.A., A.W.D.2.

1. Mr. Sargeaunt introduced the speakers from the Ministry of Aviation and the Ordnance Board, and said that the meeting was specifically concerned with the hazard from electromagnetic flash to electrical installations and equipments of all kinds. Group Captain Chettle said that it was necessary to correlate the damage radius for EM flash with those of the more obvious hazards from a nuclear burst, in order to assess its significance at any given position. A brief summary of the main effects, including nuclear radiation, would be presented, proceeding to EM flash phenomena. Thence the meeting should proceed to its main purpose, which was to obtain the views of users of equipments and installations threatened by this hazard. A knowledge of the problems in the communications and power transmission fields was necessary, in order that research could be directed to their solution. Work in this field was co-ordinated by the Nuclear Weapons Lethality Committee. This was an inter-departmental committee which was the link between the specialists working at A.W.R.E. and those in other Government departments. The staff of D.A.W.D., Ministry of Aviation, acted as executive to the committee.

2. Mr. Garrard said that information on EM flash had lagged behind that on other effects since instrumentation at earlier trials was specifically aimed at weapon design measurements. Much of the data had been accumulated incidentally in making other measurements, and was in consequence less complete than was desirable. However, a few trials had been instrumented to obtain the required parameters, and a sufficiently consistent reservoir of knowledge now existed for the formulation of a theoretical model adequate for engineering purposes.

3. Mr. Garrard showed comparative curves for damage radii for the main effects, and pointed out that only at low yields (of a few kilotons) did the radius for permanent nuclear radiation damage exceed those for blast and thermal damage. He then demonstrated the rate of emission, with a

time history beginning at 10 nano-seconds. Actually, 5% of the gamma radiation was emitted in the first microsecond, and 20% by the end of one second. To this must be added the neutron emission, which reinforced the gamma pulse by interaction with air and ground elements.

4. Typical curves for the pulse from a megaton and a nominal weapon were shown, giving time history at 1 mile and 2,000 ft. range (from burst) respectively. He pointed out that the EMP flash hazard, deriving from the ionising nature of the gamma pulse, was a transient response causing misfiring, or loss of reference in memory circuits. Neutrons, on the other hand, caused permanent damage, changing the electrical characteristics of semi-conductor components. A normal criterion for damage to transistors would be 50% loss in current gain, but sensitivity could be much greater if adjustment were critical. Neutron damage was unlikely to be significant beyond the range for severe blast damage.

5. Mr. Popham gave a brief account of the mechanism by which the ionised sphere, and hence the electromagnetic pulse, is formed. Electrons are stripped from atoms in the vicinity of the burst by the high energy neutrons and gamma radiations. The consequent Compton electrons flow outward radially, until eventually slowed down and absorbed, and a large sphere of ionised matter results. Oscillations of this sphere produce the electric field observed at a distance. The size of the sphere only varies slightly with weapon yield. About 4,000 volts/metre is the order of magnitude of the electric field expected at its surface. Time history of the EMP pulse shows a rapid rise time, in 10^{-8} seconds, a duration of about 10 to 30 microseconds, with frequencies about 10^4 cycles/second. Peak field strength increases with yield, scaling as $W^{1/3}$. Both the electric field and the corresponding magnetic field have been determined for ranges outside the ionised sphere but conditions within the sphere are not known with any accuracy. Extrapolation from observed values outside is not possible, since the highly conducting nature of the sphere distorts all the parameters.

6. Calculation of the induced currents from the field strength and dimensions of the conductor was not difficult. With a simple probe this became the product of field strength and probe length, and diminishes directly with distance from burst. Obviously with more complicated circuitry, comprising loops and sections differently aligned to the field, current strength could not be so easily assessed, and the simple calculation was not valid if the conductor approached the wave length of the pulse. However, it was apparent that large local voltages could build up, with results depending upon resistance or insulation in the circuit. Energies were comparable with those of normal radar, at distances of about 1,000 metres from the ionised sphere.

7. Mr. Niles asked if the ionised sphere could be regarded as a dipole and Mr. Popham agreed that this rationalisation was used in calculating effects, assuming a vertical axis, which appeared to be justified. In reply to Mr. Law, Mr. Garrard indicated the variation of field strengths with distance as shown by curves for electric and magnetic fields. The relation

$\frac{E}{H} = \frac{10^7}{R}$ (E in volts/metre, R in metres) was true outside the ionised sphere, but within it fields tended to be constant as a result of the high conductivity.

8. Mr. Garrard quoted some results from an actual trial with a low kiloton weapon at ground level. Peak currents in long radial wires were about 3,000 amps at 1,000 ft., and 1,000 amps at 2,000 ft. Some asymmetry was demonstrated by currents of 1,000 amps induced in transverse sections of loops. These results showed the expected order of magnitude, but that prediction at any given site would in this case have proved unreliable. Pick-up loops inside screened containers had recorded small currents out to 4,000 ft. from ground zero. Core to sheath voltages of the order of

200 to 400 volts were observed at half a mile in insulated multi-core cables, compared with a few tens of volts in the case of bare metal sheath cables. Sheath to earth polarities reached a few kilovolts in the case of the insulated cables. Fuller details of these observations could be made available.

9. Mr. Ford said that the G.P.O. must be interested in EM flash effects on their communications equipments, and had in fact instigated an assessment of the threat to one installation by A.W.R.E. at the instance of H.O.D. Obviously all installations should be considered, but he thought that the reliability of the data, as evidenced by the shot described by Mr. Garrard did not justify the work required. He thought some further confirmation desirable before undertaking comprehensive calculations of the threat. Mr. Popham said that the main features of the electric and magnetic wave forms were consistent and not based on one shot only. Mr. Garrard said that this shot had been specifically instrumented for EM flash phenomena. It did answer some questions but raised others, particularly regarding the technique of measurement. Group Captain Chettle said that there was agreement on the most important features, i.e. the phenomena outside the ionised sphere and the nuclear radiation pulse. Effects on actual equipment must be assessed by, or for, the user, since the circuitry exposed was known only to him. Mr. Kilvington said he thought that, with a fundamental frequency near 10^4 cycles per second as quoted, damage to microwave radio relays was more likely to occur from induced currents. Mr. Garrard agreed, and said that the mixer and aerial connecting cable were likely to be vulnerable. Mr. Popham quoted an actual experiment in Australia, in which a microwave radar transmitter had been aligned toward a kiloton range burst while in operation at a range of about 10 miles. It had recovered after missing one or two pulses. Mr. Franklin asked what hazard was likely with coaxial cables used in Transatlantic lines, and Mr. Garrard said that limits could be calculated, though differing types of sheathing would introduce variable factors.

10. Mr. Morley said that Home Office VHF and UHF communications installations were hardened to a 5 p.s.i. level in respect of blast, and asked how significant the corresponding frequency components of the EM flash would be at such a range. Mr. Garrard said that 5 p.s.i. corresponded roughly with 10 KV/metre and as even 1 kilovolt/metre appeared to be at about 10 times the "C" damage radius there was obviously a hazard. It should be noted that the pulse, though generally similar to a lightning flash in effect, could not be discounted in the same way as an unlikely contingency. Given a nuclear burst, an EM flash was a certain consequence, its results only being uncertain. It was faster than a lightning flash, having a steeper rise to peak value and this might make certain types of protector ineffective. Mr. Popham said that A.W.R.E. had produced an analysis of the spectrum, giving the power within frequency bands. Mr. Sargeaunt said it was apparent that calculations must be done, and suggested that Home Office Communications might be the subject of a similar investigation by A.W.R.E. to that undertaken for the G.P.O.

11. Mr. Whitcher said that power installations were likely to be less sensitive than communications. If the EM pulse were regarded as severe lightning with 100% certainty, then he thought minor damage only need be anticipated. Lightning was a hazard with which they had learnt to cope. On the other hand, they were very significant users of communications, and they must take very serious note of the points made in this field. Mr. Lott said that there was an obvious threat to computerised control systems which were currently being developed. Overhead transmission lines might also be at risk, but obviously heavy equipment would be less vulnerable than transistorised circuits. He proposed to submit figures to the Automatic Control Committee (C.E.G.B.) and would consult the Ministry of Aviation on this. Mr. Garrard offered to co-operate in evaluating the systems and equipments in question. Mr. Popham said an environmental specification was required, to which equipment should be designed.

12. Mr. Firth asked how vulnerable were crystals, as used in UHF and VHF transmission, to this hazard. Mr. Garrard said that nuclear radiation represented the threat here and that although the crystals used for carrier frequency control single channel voice communications should not be seriously affected, as little as one roentgen could do permanent damage to very high precision crystals, e.g. of one in 10^{10} accuracy. Mr. Franklin said that crystals of this order of accuracy were used in the G.P.O., so that some consideration of effects on the systems concerned was merited.

13. Group Captain Chettle said that the pattern of investigation required could only be supplied by co-operation between 3 sorts of people:

1. Theoreticians and field experiments - What the bomb does?
2. Users - What is the threat?
3. Designers - What will equipment stand?

Co-ordination of the work under these headings was obviously necessary before calculations could be made. The approach by G.P.O./W.O.D. to A.W.R.L. should be fruitful, but was not necessarily open to all users. A.W.R.E. could supply, within limitations of available staff, data on the variations in time and space of the important physical parameters after the explosion of a given bomb in a given time and place. The operating authority must specify the threat. A.W.R.E. would rarely be able to assess the vulnerability of specific equipments to the effects they calculated; this should normally be a task for the equipment designer. Ministry of Aviation (A.W.D.2 (Effects)) had information and experience in this field and would be pleased to give advice where possible. The N.W.L.C., as the appropriate interdepartmental committee were concerned to see that interdepartmental co-operation on this kind of investigation was both possible and successful. Mr. Sargeaunt said that the meeting had been very illuminating, since the nature of the hazard had been imperfectly appreciated. The lines on which work must proceed were indicated, and the users must now make an appraisal on installations for which they were responsible, to determine where screening or modification was required.

Distribution:

Those present
Mr. L.T.D. Williams, D.G.A.W.
Mr. S.A. Hunwicks, D.A.W.D.

SAN 19/7/1
SAN 13/7/2

Mr. N. Morley
Communications Branch

Mr. Firth has raised the question of the possible effect of the HE flash on the survey meter at the KOC posts. The ion chamber is at a position 3 ft. above ground level but most of the vertical cable running down into the post is surrounded by the steel supporting tube so I should have thought it would be safe enough, but this is really outside my field. Deacon knows the instrument itself very well, and perhaps between you you could let Firth have a considered opinion.

The KOC post and the instrument mounting above ground are designed to stand 50 psi.

21st October, 1964.

Scientific Adviser's
Branch.

From: Mr. H. A. Sargeaunt, CB, OBE.
Chief Scientific Adviser.
Victoria 6035. Ext: 5.3.

39

SAS/62 10/7/1 23rd October, 1964.

Dear

Your presentation and that of your team at the Home Office was a great success and I have had several appreciative comments from those who attended. If you would thank Mr. Gerrard and Mr. Popham on our behalf we would be most grateful. I do hope that the discussion afterwards was of help to you. It is never easy to make sure that all the points are brought out but my general impression was that very useful contacts were made. You yourself have obviously a difficult task in keeping in contact but I can see nobody else who can ensure that the technical information of one department is passed on to others or the need to know basis. For instance, I am certain that the work which the Ministry of Power are apparently proposing to do on computers ought to be available to the Home Office and to other people as well.

I am having a word with Sir Walter Morton who will [illegible] of these [illegible] will be getting in touch with you later.

Again thank you so much.

Yours sincerely,

Gp. Capt. P. M. Chettle,
AD/AVD 2,
Ministry of Aviation,
St. Giles Court,
St. Giles High Street,
London, W.C.2.

Meeting in Room 208, at 10·30, Tuesday Oct. 20th 1964.

List of those expected:-

NAME	DEPARTMENT	REMARKS
Group Captain Chettle		
Mr Garrard	Ministry of Aviation	Lecturer
Mrs Willcie	A.W.D.	Secretary, N.W.L.C.
Mr Popham	Ordnance Board	Lecturer
Mr Sargeaunt	Home Office, S.A.B.	
" Leader Williams		
" Stanbury		
" Yaury		
" Miles.		
Sir Walter Merton	Home Office	
Mr Firth		
Mr Collyer		
" [illegible]		
" Law.		
Mr Morley	Home Office Communications Branch.	
" Brooker		
" Watson		
" Glaysher		
Mr Ford	G.P.O.	
" Kilvington		
" Franklin		
Mr Mott	Electricity Industry	Nominated by Min. of Power.
" Witcher		
Mr Hurst	Ministry of P. Bldgs + Wks.	
Col. W.T. Armour	Ministry of Defence	Nominated by A.W.D.

37

Reference ..... X4/306/21.

Civil Science Interests.

Effects of E.M. fields.

Dear Mr Farrell,

I enclose

[illegible] Formula [illegible]

this week [illegible]

received have been sent

on here to Mr F. [illegible]

for Romour.

Mr Garrard

Capt. Chettle

[illegible]

Mr F. Farrell.

[illegible]

Have effect

[illegible]

CODE 18-76

XY/306/01

Effects of Electro-magnetic Pulse from
a Nuclear Weapon on Civil Defence Interests

The meeting will be held in Room 208,
Horseferry House, Dean Ryle Street, S.W.1.
at 10.30 a.m. on Tuesday, 20th October, 1964.

AGENDA

1. Introduction. Mr. Sargeaunt and Gp.Capt. Chettle.

2. Effects

   (a) Nuclear Radiation at Early Times — Mr. D.J. Garrard.

   (b) (i) Electro-magnetic Pulse — Mr. E.D. Dracott.
   (ii) Induced Currents and voltages — Mr. T.S. Topham.

3. General Discussion.

Mr. Firth

Would you please let me know if you propose to attend the meeting on October 20th, and whether you wish to bring anyone with you?

I shall be responsible to the Ministry of Aviation on Security, so I need to know who will be present.

14th October, 1964.

Scientific Adviser's
Branch.

Mr. Slater
Establishment Division

I spoke to you recently about a Symposium it is proposed shall be held here on October 20th in conjunction with the Ministry of Aviation.

I understand that the presentations will be mostly in the Confidential security range, but that it would be preferable to know that all those attending are cleared for Secret, since that would give the lecturers more freedom in answering questions. I have now been able to compile a list of those expected to attend, and give the names below. The only ones I have not so far had are those to be nominated by Mr. Firth.

If you should need to consult the Security Officer in Aviation at any stage, you may wish to know that the Symposium is being arranged by A.W.R.E., St. Giles' Court. It is on the subject of the electro-magnetic effects of nuclear explosions. Mrs. Wilkie, of A.W.R.E., is concerned with the arrangements.

F.H.Pavry

9th October 1964
S.A.B.

Home Office:- Mr. Sargeaunt
Mr. Leader Williams
Mr. Stanbury
Mr. Pavry
Sir Walter Morton

/Mr. Collyer

P.T.O

H.O. (contd.)	Mr. Collyer	
	Mr. Morley	
	Mr. Brooker	
	Mr. Watson	
	Mr. Glaysher	
Min. of P.B. & Works:-	Mr. C. E. C. Hurst	
Min. of Power:	Mr. A. R. D. Murray, who is bringing:-	
	Mr. Witcher)	of the Electricity
	Mr. Mott)	Supply industry
G.P.O.:-	Mr. Ford)	Attendance arranged
	Mr. Silvington)	through Mr. Brooker
	Mr. Franklin)	

MINISTRY OF POWER
ESTABLISHMENTS DIVISION
Thames House South, Millbank, LONDON S.W.1
Telephone: Abbey 7000

Our reference: 15/9/01

Your reference:

11th September, 1964.

Dear Pavry,

You spoke recently about a proposed half-day symposium on the electro-magnetic pulse. This is to let you know that Messrs. Whitcher and Mott of the Electricity Supply Industry will be willing to join in; I would also like to come along as an observer if you are prepared to have a layman in your ranks.

Doubtless you will give us good notice of the date.

Yours sincerely,

(A. R. D. Murray)

F. H. Pavry, Esq.,
Scientific Advisers' Branch,
Home Office,
Horseferry House,
Dean Ryle Street,
London, S.W.1.

VT

531

28th August, 1964.

Dear Garrard,

E.M.P. Symposium

I have not been in touch with you since our talk on the 20th because I thought we should get Mr. Sargeaunt's views, and he was away until yesterday. He agrees that we should concentrate on the effects of nuclear radiation and E.M.P., with a good long period for discussion; any points about thermal and blast effects could be covered in this period.

I enclose a copy of a revised draft Agenda.

It looks as if there will be about twenty-four people wishing to attend. We would appreciate as much notice as possible of the date or dates that would suit your Department, so that we can give the more important customers the best chance of being available.

Yours sincerely,

F.H.Perry

D. J. Garrard, Esq.

A.W.D.
Ministry of Aviation
St. Giles' Court

32.A

Revised Draft Agenda

Proposed Symposium on Nuclear Weapon Effects, with particular reference to the effects of Electro-magnetic Pulse on Civil Defence interests, including Communications and Power

(To be sponsored by Ministry of Aviation, and held at the Home Office.)

	Estimate of Time
1. Introduction	
Mr. Sargeaunt and Group Captain Chettle	10 minutes
2. Effects	
(a) Nuclear Radiation	50 minutes
(b) (i) E.M. Pulse	
(ii) Induced currents and voltages	
3. General Discussion	1½ hours
	2 hrs. 30 mins.

~~CONFIDENTIAL~~

List of those expected to attend

~~List of Visitors~~ Proposed Symposium at the Home Office

S.A.B. : Mr Sargeaunt
- " Stanbury
- " Leader Williams (X)
- " Parry

Others'

Comms. Br. Mr Brooker
- Morley (Elgood's deputy).
- Watson
- Glaysher

C.D. Dept. . Sir Walter Merton ✓
~~Mr Firth + 2 extra~~ A.I. Div 3/4 places
Mr R.L. Jones ✓ (Can come (see minute 28.4))
Mr Collyer. ✓

M P B W. Mr Hurst ✓

M. of Power

G P O. Mr Ford
- " Kilvington
- " Franklin.

~~H.O.~~

M/s Parry

Mr. Stanbury

Electric-magnetic Effects

We discussed your minute of 18th August about the proposed half day Symposium, and I explained that it was difficult for us at this stage to say firmly what our requirements would be for the Warning and Monitoring Organisation. Provisionally, however, we should like to bid for three or possibly four places.

20th August, 1964.

A.G.

Mr. Stanbury

Thank you for sending me a copy of your minute dated 18th August 1964, addressed to Mr. Firth and Mr. Jones. I would very much like to listen-in to what is said at the proposed symposium. As I have a number of engagements already fixed for October I would be most grateful if your P.A. would liase with mine so that a day on which I am free can, if possible, be selected.

19th August, 1964.

Civil Defence Department
Horseferry House

Dr. Stanbury
Scientific Advisers Branch

Electric-magnetic Effects

If possible, I should like to attend the half-day discussion myself, and I should also like Mr. Collyer to attend.

19th August 1964

A.2 Division

First draft — taken to discuss with Garrard 20.8.64, 27 February

CONFIDENTIAL

Proposed Symposium on Nuclear Weapon Effects, with particular reference to the effects of Electro-magnetic Pulse on Civil Defence interests, including Communications and Power

(To be sponsored by Ministry of Aviation, and held at the Home Office.)

TENTATIVE AGENDA

	Estimate of Time	
		U.K.F. Symposium
1. **Introduction**		
Mr. Sargeaunt and Group Captain Chettle	10 minutes	5
2. **Effects**		
(a) Blast (b) Thermal Radiation (c) Nuclear Radiation (d) (i) E.M. Pulse (ii) Induced currents and voltages (e) Synthesis	50 minutes	50
3. **Target Response** (a) Blast (b) Thermal Radiation (c) Nuclear Radiation (d) E.M. Pulse	25 minutes	30
4. **Relevance to Civil Defence**	5 minutes	20
5. **General Discussion**	1 hour	30
	2 hr. 30 mins.	2 hr. 15 mins.

(See attached Notes on Agenda.)

NOTES ON TENTATIVE AGENDA

	Estimate of Time
1. Introduction and purpose of Symposium	10 minutes
2. (a) Blast Effects	10 minutes

Essentially the phenomena associated with blast wave in air. Ground reflection, mach stem and precursor effects only significant for case of items on or near ground. Detail therefore required on over pressure, dynamic pressure and wind velocities, as modified by yield and altitude. The effects up to 10-20 p.s.i. only need be covered.

(b) Thermal Radiation Effects including X-rays and Thermal Gamma — 10 minutes

The nature of the thermal pulse in duration and intensity and variation of these with yield and height of burst. Attenuation of thermal pulse by atmosphere and the effects of meteorological conditions. Reflections from ground or cloud layers, or both. Thermal energy - distance relationship at low and high altitudes. Brief description of X-rays, Thermal gamma and energy deposition in the atmosphere.

Thermal weapon threat.

(c) Nuclear Radiation Effects — 10 minutes

The nuclear radiations produced by a bomb and the time history of their arrival at any particular point.

Accumulated doses of each type in relation to time, ~~and hence target motion, height etc.~~ The time periods of interest lie between a fraction of a microsecond and one minute, thus covering rate effects which affect such things as electronics and total dose effects which affect such things as people and photographic materials.

(d)(i) Electromagnetic Pulse — 15 minutes

The origin of the E.M. Pulse and theoretical model. Wave form and energy of magnetic and electric pulses. Nature of electric field inside and outside the "ionised sphere". Energy - distance relationships and their modification by yield and altitude.

(ii) Currents and Voltages induced by E.M. Pulse in systems.

(e) Synthesis of Effects — 5 minutes

Comparative ranges of various effects. Damage - distance relationships and the effect of modification by yield, altitude and atmospheric conditions on estimation of the critical hazard.

3. Target Response

(a) Blast — 5 minutes

Vulnerability of communications equipment and systems to blast. Similarly for power generation and distribution.

(b) Thermal Radiation — 5 minutes

Vulnerability of communications equipment and systems to thermal radiation. Similarly for power generation and distribution.

(c) Nuclear Radiation — 5 minutes

Vulnerability of communications equipment and systems to nuclear radiation. Similarly for power generation and distribution.

/(d)

	Estimate of Time
(d) E.M. Pulse	10 minutes

Vulnerability of communications equipment and systems to E.M. pulse. Similarly for power generation and distribution.

4. Relevance to Civil Defence	5 minutes

C.S.A. Home Office will indicate the relevance of the E.M. Pulse data to the interests of Civil Departments, and instance any aspects of particular importance. This can be in the nature of an introduction to the final item.

5. General Discussion	1 hour

A discussion on the extent to which Civil Departments can, or should, incorporate measures to protect from E.M. Pulse.

	2½ hours

Copy sent to Scientific Adviser's Branch

Mr. Firth
A.6 Division

Mr. R. L. Jones
A.2 Division

[redacted]

We are trying to arrange a half-day conference, especially for officers, at which the Ministry of Aviation will describe recent developments in guidance and other equipment, with particular reference to the electromagnetic effect.

The purpose is to make sure, that the [illegible] Ministry of Aviation interests is informed.

I gather that [illegible] a list of those who may wish to attend, so would you let me know if you expect to come, and if there is anyone else you want to suggest. We will, of course, [illegible] more details of date, etc., as soon as we have them. The meeting is likely to be in Horseferry House.

18th August, 1964.

Scientific Adviser's
Branch.

COPY

Mr. Firth A.6 Division

Mr. R. L. Jones A.2 Division

Electro-magnetic Effects

We are trying to arrange a half-day Symposium, possibly in October, where the Ministry of Aviation will discuss weapon effects on communications and power supplies, with the main emphasis on the electro-magnetic effect.

The purpose is to keep Communications Branch, the R.A.E. and Ministry of Power interests informed.

I gather that Aviation will get a list of those who may wish to attend, so would you let me know if you expect to come, and if there is anyone else you wish to suggest. I will, of course, let you have more details of date, etc., as soon as we have them. The meeting is likely to be in Horseferry House.

18th August, 1964.

Scientific Adviser's
Branch.

Mr. A. R. D. Murray
Ministry of Power

We are trying to arrange a half-day Symposium for some time in October, at which experts from the Ministry of Aviation will discuss nuclear weapon effects, with special reference to the effects of the electro-magnetic pulse on the interests of Civil Departments, notably communications and power.

This really carries a stage further the meeting in March 1962, when we arranged with Mr. Stuart for a scientist from Aviation to discuss e.m. effects with a group including engineers from Electricity Generating Boards.

Aviation want a list of those who would attend the Symposium, so would you please let me know any names you wish to be included.

I will, of course, let you have more details as soon as they are available. The meeting is likely to be in this building.

F.H.Lavery

18th August, 1964.

Scientific Adviser's
Branch
Home Office
Horseferry House
Dean Ryle Street
S.W.1.

EB

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COMMUNICATIONS BRANCH
HOME OFFICE
Whitehall, LONDON S.W.1
Telephone: WHItehall 8100, *ext.* 332

Our reference: COM/64 71/4/1
Your reference:

12 August 1964

Dear Pavry,

Electro-magnetic effects

I passed the proposal in your note of 2nd July, 1964, reference SAN 19/7/1 to Ford and now have the names of the people who would wish to be at the Seminar. They are:-

K. H. Ford	Principal ITD
T. Kilvington Staff Engineer	Radio Planning and Provision Branch
R. H. Franklin Staff Engineer	LMD

Our Branch would be represented by Morley, Watson, Glaysher and myself.

I gather Ministry of Defence has raised the question of co-ordination with the Cabinet Office, but I've no idea how the matter goes.

Yours sincerely,

J Worth

P.S. Typing is a little delayed and in meantime your names of the prospective guests have been passed to Mr E.W. S/C

JW

F. H. Pavry Esq.
Scientific Advisers' Branch
Horseferry House
Dean Ryle Street
S.W.1

22

SECRET

HOME OFFICE
Whitehall, LONDON S.W.1
Telegrams: Monobis Parl London
Telephone: WHItehall 8100, *ext.* 532

Please address any reply to
THE UNDER SECRETARY
OF STATE
and quote: COM 64 71/4/1
Your reference:

6.8.64

Dear Barony,

E.M. Effects

You may wish to have this
copy letter to see how it is proposed
co-ordination should be effected. I gather
MoD thought the C.C.C. rather over large
for this subject and as Elgood is on
the EW Sub-Committee we have no objection
to the proposal. The important thing is
that all interested parties should have
available

SECRET

available the threat to their particular interest and so far as I am concerned this is primarily the likely damage to interference to line and radio communications systems.

Yours sincerely

J.D. Scott

J.H. Pawsey Esq
SAB

Copy to N.H. Elgood, Esq.

SECRET

SECRET

30th July, 1964

Dear Foden,

Electro-Magnetic Effects of Nuclear Bursts on Communication Systems

Thank you for your letter of 24th July, reference D/DSS/122/3(AS(T)). I have spoken to Gen. Thuillier about your proposal, and in his view the most appropriate forum for a discussion on the co-ordination of departmental studies in this field would be the Electronic Warfare Sub-Committee of the Combined Communications-Electronics Committee, as discussion in full at this stage would probably be premature and might involve too wide a distribution of information.

I should therefore be glad to have from you a memorandum on the study which the Ministry of Defence propose to initiate in due form for circulation to the Electronic Warfare Sub-Committee, for which we require 35 copies.

On the first paragraph of your letter, I gather that although the Home Office and Post Office have been discussing this matter, they have not in fact reached the stage of preparing a memorandum for the C.C.C., but I believe that the Ministry of Aviation may also have an interest in this matter.

As there might be a meeting of the Electronic Warfare Sub-Committee during August, it would be helpful if we might have your memorandum as soon as possible.

I am sending copies of this letter to Elgood (Home Office), Mumford (Post Office) and Tyndall (Ministry of Aviation).

Yours sincerely,

(J.E. FRASER)

Air Cdre. A. Foden,
Ministry of Defence,
Main Building,
Whitehall, S.W.1.

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NWLC/M(64)1 XY/337/02

MINISTRY OF AVIATION

NUCLEAR WEAPONS LETHALITY COMMITTEE

Minutes of the Seventeenth Meeting held on Tuesday, 30th June, 1964 in Room 458, St. Giles Court, W.C.2.

Present	Branch or Post	Representing
Mr. L. T. D. Williams	D.G.A.W.	In the Chair
Mr. J. K. L. Thompson	D.Sc.3 for Mr. Fakley	M.O.D.
Cdr. P. B. Grotrian	D.G.A./N.	D.C.N.S.
Mr. J. H. Williams	D.W.P.R.	M.O.D.(N)
Col. R. Bellingham Smith	M.G.O. Nuclear	M.G.O. & D.C.G.S.
Mr. J. W. Gibson	"S" Divn./O.B.	Ordnance Board
Gp. Capt. A. J. Peart	D.D.O.R.10 (R.A.F.)	D.O.R.3 (R.A.F.)
Col. T. W. Armour	G.W.(P. & W.) for Dr.Errington	C.G.W.L.
Mr. R. D. Starkey	A.D./A.D....	C....
Miss V. A. Davies	M.E./R.A.E. for Mr. Bisby	D./R.A.E.
Mr. F. E. J. Girling	R.R.E.	D./R.R.E.
Mr. E. R. Drake Seager	S.F.P./A.R.D.	D./A.R.E.
Mr. S. D. Abercrombie	S.P.A.2/A.W.A.	D.A.W.R.E.
Col. H. W. Whitcher	D.C./A.W.S.	Panel N1 Sub.Cp. N.
Mr. S. A. Hunwicks	D.A.D.	M.O.A.
Gp. Capt. P. F. Chettle	A.D./A.W.D.2	M.O.A.
Mrs. M. E. Wilkie	A.W. Plans	Secretary

The following also attended

Mr. P. J. Atkins	S.F.P./A.W.E.	D./A.W.E.
Mr. J. C. Litton	"S" Divn./O.B.	Ordnance Board
Mr. F. H. Pavry	S.A.B./H.O.	Home Office
Mr. D. J. Garrard	A.W. Plans	M.O.A.

Apologies for absence were received from

Mr. D. C. Fakley	M.O.D.
Mr. D. H. Chaddock	D. of A. (R. & D.)
Mr. G. J. Laing	D. of A. (R. & D.)
Mr. G. R. Stanbury	Home Office
Mr. J. D. Davies	A.W.A.E.

Item 1. Minutes of the last meeting

1. The minutes of the last meeting were accepted without amendment.

Item 2. Matters arising

2. Actions 16-1 and 16-2. Consideration of these actions was deferred to Items 4(b) and 3(c) on the Agenda, respectively.

3. Action 16-3. Mr. Gibson said that the Committee's directive had been noted. This must, of necessity, be a continuing action. Draft minutes of the last Sub-Group N meeting had been prepared and were now under consideration by the U.S. and Canadian members before final publication. He said that the question of these minutes being made available to the A. B. C. A. Standardization Group had not yet arisen, but agreed that it was unlikely that such a request could be granted.

SECRET

4. Actions 16-4 and 16-6 were noted as having been completed.

5. Re Item 16-5. Mr. Garrard said that the original directive had been complied with, and that a contract had now been made through R.A.E./Weapons Dept. with Standard Telecommunication Laboratories, who were now engaged in drawing up a programme of work. A meeting with interested parties had been held to discuss information from the recent JOWOG-6 visit to U.S.

Item 3. Tripartite Technical Co-operation Programme. Sub-Group N. activity

6. Mr. Gibson said that the last Sub-Group meeting in October 1963 had already been discussed by the Committee. The next meeting was proposed for October 14th-15th, preceded by a Panel N1 meeting in September, both taking place in Canada. Panel N2, most of whose personnel were in Suffield for the current trial, planned to have a meeting there following the 500-ton explosion. Panel N3 had held its first meeting in U.S. in April, and details of this and future meetings would be given by Mr. Drake Seager. It was planned to review reports from the Panel Leaders in September, as a preparatory briefing for the October meeting, and, among other subjects, the U.K. views on the future use of the Suffield site should be defined by this time.

Item 3(a). Report from Panel N1

7. Col. Whitcher referred to the last Panel N1 meeting in October 1963 and said that difficulties in implementing actions arose from the delay in issuing minutes, since these were in effect the authority required for any action. In this case the U.S. were responsible for the issue of minutes. The Panel noted and decided to support the U.K. work on biological effects of nuclear radiation. This included neutron effects on large animals, which was proceeding, but for which firm results were awaited before publication, and the effects of low gamma dose rates upon rats. Here, using food consumption as indicator of the effect, a definite response at 2.7 r./hr had been established, with uncertain results as yet at lower dose rates. The current Services trials of the U.K. chemical protective garment were noted, and it would be compared with the efficacy of the Canadian Nimbus cloth, when the final report on the latter was received. The need for radiac instrumentation in the field had been queried by the Panel, but the logical step of representing this view at the next Quadripartite Standardisation Group meeting could not be taken in the absence of the minutes. The Quadripartite Group had already fixed the standards for water potability so that there was no need for the Panel to consider this question further. In conclusion, Col. Whitcher referred to the Suffield trial and said it was hoped that this would produce more information on blast effects on large animals.

8. Mr. Gibson said that the T.T.C.P. procedure was for meetings to be held in rotation in the three participating countries with the host country providing the Secretary. In the case of the Sub-Group meetings, issue of the formal minutes is the responsibility of the Executive member. For panel meetings it had been proposed that the host country should provide the Chairman as well as the Secretary, and, if this was agreed, it seemed reasonable that the host country should also issue the minutes. Col. Whitcher agreed with this, and said that the Panel N1 draft minutes in this case had been prepared by the U.K., but left for the U.S. to issue, as this was considered a function of the permanent administration between meetings. Mr. Gibson said that the degree of authority, apart from co-ordination, of the Sub-Group with reference to its Panels was not clear to him. He proposed to follow the procedure adopted by other Sub-Groups, of collecting reports from the Panels and drawing up an agenda for the full Sub-Group meeting from their recommendations. The Chairman said that this pattern seemed sensible. Col. Whitcher said that the work of Panel N1 was further hampered by the lack of any clear authority to support its work, which by reason of its diversity required the co-operation of different establishments, including the R.A.C., Aldermaston and hospitals. He did not propose increasing the formal membership of the Panel, since

LH.1V

Tel. No.: Museum 3644

Extn. 238

Your Ref.

Any communication on the subject of this letter should be addressed to:
THE SECRETARY
and the following reference quoted:
XY/337/02

SECRET

MINISTRY OF AVIATION
Room 840,
St. Giles Court,
1-13 St. Giles High Street,
LONDON, W.C.2.

7th August, 1964.

Dear Mr Pavry

Nuclear Weapons Lethality Committee

It has been pointed out that an error has arisen in the minutes of the 17th meeting. This should be corrected as follows:-

p.3. para.10. lines 8-11. Delete sentence:

"It had been held ..... JOTOG-19"

Replace by:-

"The mass fire problem resulting from a burst of large yield at high altitude was included in the Panel N3 field, but it had been held that the response of weapons systems to high thermal fluxes was of higher security than allowed for on Panel N3 discussions, and was therefore more properly to be considered by JOTOG-19."

This amendment resolves the discrepancy between the minutes and the statements made in Mr. Drake Seager's paper N.L.C/P(64)3.

Yours sincerely,

M.D. WILKIE
Secretary, Nuclear Weapons
Lethality Committee

Distribution:-

Membership of N.W.L.C.

SECRET

changing emphasis in its interests required a flexibility in personnel which could be more easily provided on an informal basis. The Chairman considered that the attention of the Sub-Group and, if necessary, of the Washington deputies should be drawn to these difficulties, resulting from delay in issuing minutes.

Action Mr. Gibson

Item 3(b). Report from Panel N2

9. Mr. Gibson said that this must be confined to noting the current trial at Suffield with, of course, Panel N2 personnel engaged on the site. A panel meeting would be convened after the explosion, and the Committee could look forward to some report on the trial at its next meeting. Mr. Drake Seager said that he had visited Suffield earlier this year and found preparations going well, and a general expectation that the proposed date, now July 16th, would be met.

Item 3(c). Report from Panel N3

10. Mr. Drake Seager referred the meeting to the prepared Paper NWLC/P(64)3, containing a report of the first meeting of Panel N3 and surveys of thermal radiation and fire research work in the U.K. and Canada, and a list of U.S. organisations engaged in this field. Thermal radiation problems of interest to all three countries had been defined, and these included the characteristics of the thermal pulse, with modifications due to yield, height of burst and attenuation, the ignition characteristics of materials, and thence to problems of the spread of fires, especially in urban areas. [~~It had been held that the mass fire problem resulting from a burst of large yield at high altitude was of higher security than allowed for on Panel N3 discussions and was therefore more properly to be considered by JOWOG-19.~~] Apart, however, from this security reservation, the allocation of effects on personnel to Panel N1 shifted the emphasis of interest in Panel N3 to large weapons and civil defence counter-measures. He considered that the U.K. had a good deal to offer in this field, being in some ways better organised than either the U.S. or Canada. For example, the U.S. had no organisation specifically concerned with urban fires, the responsible body being the U.S. Forestry Commission, which could not be regarded as parallel to the Joint Fire Research Organisation in this country. Canada found her efforts embarrassed by provincial autonomy, and co-operation from state fire chiefs was not satisfactory. It had been noted that there was little university work on fire research in any of the three countries. Regarding exchange of personnel, it was considered that working visits of 2-3 months would be more valuable than short visits. The Chairman said that such exchanges were a declared T.T.C.P. objective, but that the provision of money for them caused difficulty in all three countries. Endorsement by the office of the Chief Scientific Adviser in M.O.D. should be sought. Mr. Drake Seager said it had been agreed to hold a symposium on thermal radiation problems in the U.K. this autumn. This would now be 5th-9th October at the Fire Services College, followed by a panel meeting in London on the 12th October to precede the Sub-Group meeting. The Panel hoped soon to produce bibliographies covering the work done in its field, one to be unclassified and the other up to the permitted SECRET security level.

See revision of this

11. The Chairman thanked Mr. Drake Seager for an encouraging account of the Panel's work, and noted the Terms of Reference at Annexure B, in particular the exclusion of biomedical effects. Some discussion followed on the difficulty of accommodating problems of burns and flash blindness between Panels N1 and N3, and Col. Whitcher said that these were a medical and inter-service problem, not specifically nuclear weapon effects. Col. Bellingham Smith said there must be concern for troops, and consideration given to the soldier in a burning truck or with ignited clothing. Personnel in other services must also be subject to such hazards. Mr. Garrard drew attention to other possible omissions from the Panel N3 field such as aircraft, re-entry vehicles and weapons systems, and in particular the U.S. reticence on weapons systems on security grounds. Mr. Drake Seager thought the last point could be discussed with the U.S. members, and also suggested that the M.O.A. "Damage Manual" could be made available to

Canada, to which Mr. Garrard agreed. In reply to the Chairman he said that underwriters concerned with fire insurance were members of the National Fire Protection Association. The Chairman asked Mr. Drake Seager and Col. Whitcher to discuss the areas of interest of their respective panels and agree on the delineation between them. Action Colonel Whitcher Mr. Drake Seager

Item 3(d). Future use of Suffield Experimental Station

12. Mr. Gibson referred to Paper NWLC/P(64)2 and said he wished to thank the Secretary for preparing this in view of the pressure on Mr. Laing. It represented the initial response to Mr. Longair's request at the last Sub-Group N meeting. He thought the paper gave a fairly clear summary of the position, though details must of necessity be vague. It could be expressed briefly as a continuing but diminished requirement, using Suffield for less frequent but larger firings. Mr. Hunwicks said that questions of policy and funding must also be involved, and Mr. Gibson said that this also applied to the Canadians. He understood that the U.S. were carrying out quite a large programme of H.E. firings in Nevada, independently of Suffield. The Chairman said that the paper, subject to revision by the Committee, could be used to express their views to the Chief Scientist M.O.D. (Army), so that he could instruct the U.K. leader for Sub-Group N for its next meeting. He said that the heading should be amended for this purpose. Mr. Drake Seager said that para. 6, p.3, overstated the case for A.W.R.E., and wished to amend "would be interested ..." to "might be interested ...". He also thought that the reference to WOPS 100 at the end of the paper should be amended. The Chairman accepted these amendments, and the Committee agreed to the subsequent use of the paper as an expression of their views. Action Secretary

Item 4. Nuclear Weapon Radiation Effects on Electronics

Item 4(a). JOWOG-6 Visit to U.S.A.

13. Mr. Garrard passed round copies of a paper giving an outline of this visit, showing establishments visited and subjects discussed. These establishments included Northrop Ventura, General Atomics, Boeing Aerospace Division, Sandia Corporation and Harry Diamond Laboratories. A wide range of subjects within the field of nuclear radiation effects was discussed. The knowledge of effects on micro-miniature circuits, in which the Committee had now interested itself, appeared to be at a correspondingly early stage in the U.S., and most of the organizations named were engaged in such studies. Some phenomena which seemed to be peculiar to these circuits had been noted. More attention was now being given to secondary photo-current effect on transistors, first made evident at "Small Boy," in which release of carriers by the prompt pulse completely altered the reaction of the component to subsequent pulses. There was an increasing awareness of the hazards to missile systems, some at quite small radiation levels, but the U.S. security screen on missile systems, as such, was a barrier to comprehensive information. Mr. Garrard noted U.S. concern in the following specific fields:-

a) Guidance computers can actually be stopped by a low dose (i.e. long range effect) of radiation, thereby aborting the mission.

b) The X-ray pulse from a burst at high altitude represents up to 80% of the energy yield. The 10-30 Kev tail of this 'thermal gamma' pulse could be a threat to thin-skinned vehicles. It is considered that this problem can be overcome but must, nevertheless, be kept in mind.

c) Fundamental work on response of circuits to environments is less sensitive to security barriers, but it is realised that more precise analysis of radiation environments is necessary to assess the hazards to components and circuits.

14. Mr. Abercrombie gave an account of the Symposium on E.M.P. effects at Bedford, Massachusetts. This was held 22nd-26th May, and was therefore concurrent with some of the other visits arranged through JOWOG-6. Discussions covered the further analysis of the "Small Boy" results, on Mr. Abercrombie noted that this had resulted in closer agreement between U.S. and U.K. on their interpretation. A summary of the U.K. work on the "close-in" field was given. The effects of the nuclear radiations, in particular of the secondary gamma derived from the neutron pulse, on the form of the electro-magnetic pulse was examined. There was a session on shielding devices, including protection of cables, and an account of simulation work at A.F.W.L. Devices used for this include an elaborate tapered structure, 30 feet in width, which produces a travelling wave, and a trailer which carries a Marx generator, consisting of 5 units each producing 2 megavolts, which can be used in various combinations. The problems of missile in flight were examined, but U.K. members were excluded from discussions of missile systems for reasons of security.

15. Mr. Abercrombie also reported on the JOWOG-24 meeting in the U.K. from 23rd-25th June, 1964, which also dealt with the E.M.P. field. There was an exchange of data, and both U.S. and U.K. are preparing summaries of the information so far established. The interpretation of the "Small Boy" results is continuing, but is hampered at A.W.R.E. by lack of staff. The main effort is being concentrated on the formulation of a satisfactory "close-in" theory, since phenomena within the ionised sphere are imperfectly understood. There are A.W.R.E. experiments at Suffield to record the E.M. effects, at 30 feet above and below ground, the fireball expansion and the distortion of the earth's field. There is current U.S. work on underground shots in Nevada. A technique for containing the burst had been satisfactorily developed, but electro-magnetic effects were distorted by the conditions.

16. The Chairman asked if electro-magnetic effects were regarded as a real hazard under operational conditions, and Mr. Garrard said that this was the U.S. opinion. It was apparent that the problem depended upon the design of the particular equipment and with the U.S. reticence on missile systems the information available was incomplete.

17. Item 4(b). E.M. Flash Hazard to Equipments

Gp. Capt. Chettle referred to Action 16-1, requiring the formation of a small panel to co-ordinate knowledge of this hazard. He found that, in effect, this already existed in the E.M. Flash Panel of the Committee, which had itself been unable to proceed to the production of a guide for designers and producers. He had found considerable ignorance of the problem among users, who were not convinced of its importance. Designers had noted the effects, but believed other hazards to be of greater importance. He proposed to arrange discussions between those responsible for operational requirements in specific fields and a small team of experts, effectively the E.M. Flash Panel. He hoped in this way to identify specific problems, in each field in which they existed. He had already started action to bring about the first of these short seminars which, for convenience would be with M.O.D. (Air) operational requirements and signals staffs. If this was successful the discussions would be repeated with other bodies. Mr. Pavry said that he would like to be kept informed so that the Civil Departments could take advantage of these arrangements.

18. Mr. Thompson said that the Ministry of Defence had received a request from Bomber Command, to assess the danger to communications arising from E.M. flash. This problem had been referred to A.W.R.E. Mr. Pavry said that the G.P.O. were involved in this, and there were also Civil Defence and telecommunications aspects. He had been informed by the G.P.O. that M.O.D. authority was needed for action. It seemed that this had been obtained. Mr. Abercrombie said induced currents in underground cables and land-lines must be considered, along with the power supply and telecommunications involved. There had been a meeting at Aldermaston with the Bell Telephone Co. to correlate effects with results from Small Boy. They would supply an answer related to the estimated field strength. The Chairman said that he was glad to note that there was now a specific problem on the way to solution. He asked Gp.Capt. Chettle to keep in touch with this work. Mr. Girling said that the diverse factors

contributing to this problem showed the difficulty for those concerned with weapons systems. Operational requirements could only refer in vague terms to the hazard, and Gp. Capt. Peart agreed that this was what had happened at the Air Ministry.

Item 4(c). E.M.I. Report of Fuze Experiments at D.O.R.F.

19. Gp. Capt. Chettle said that a meeting chaired by D.S.R.(L) had considered this report, and agreed that the results should have a wider distribution than that made so far. R.R.E. had agreed to prepare an abstract to summarise the knowledge gained at these tests. Mr. Girling said that the establishment of mistriggering and permanent damage levels with respect to the reactor pulse did not necessarily establish where these levels cam in a bomb environment. He recognised two sources of error in attempting translation of results in terms of a reactor environment to those of a bomb environment. It would be possible either to proceed beyond the limits justified by the data, or by keeping within the established limits, to produce an interpretation too vague to be of use. The mistriggering mechanism, different for each fuze, also appeared to differ for the two types of environment. He was at present unsure of the value of the paper that could be extracted from these results. Mr. Garrard welcomed this analysis and agreed to discuss the results further with Mr. Girling.

Item 5. N.A.T.O. Symposium on Effects of Nuclear Weapons on Underground Structures

20. The Chairman said that he must omit this item from the Agenda in view of the time taken over the foregoing discussions, and apologized to those interested.

Item 6. Any other business

Item 6(a) Paper NWLC/P(64)4

21. The Secretary announced the distribution of Paper NWLC/P(64)4 to U.S. and Canadian recipients of A.W. Plans Note 45, which was the primary reason for its production, in response to their request at the last Sub-Group N meeting. It had also been made available to Committee members. Miss Davies asked why, if "DISCREET" material had been made available to Canada, as in this case, some reports in this category had been omitted. The Secretary replied that this had been agreed between the originator and T.I.L., who had prepared this bibliography. The Chairman said that it seemed to be a very good piece of work, and asked the Secretary to express the Committee's appreciation.

ACTION Secretary

Item 6(b). Reports on "Buffalo" and "Antler" trials

22. Mr. Drake Seager said that he would like to have the Committee's opinion on the desirability of completing the publication of the reports from these trials. There were about 6 (of 40) outstanding, and these were unlikely to be printed unless the Committee asked for them, since Technical Services at A.W.R.E. regarded other work as more pressing. The Chairman said that he had previously observed with concern that A.W.R.E. apparently face difficulties in producing reports in times comparable with other Establishments and that delays of some years after the carrying out of the relevant experiments were not unknown. In the cases mentioned by Mr. Drake Seager, the experiments had been carried out more than six years previously. He thought it would be most unfortunate if Departments were to be deprived of even a part of the information derived from these trials, which had cost so much in money and effort to mount, and he said that the appropriate Division of A.W.R.E. should be asked to expedite the publication of these missing reports.

ACTION MR. Hardwicks

Item 7. Date of next meeting

This was left open, to be notified at some future time.

Summary of Actions

Action 17-1 Mr. Gibson	To bring to the notice of Sub-Group L, and if necessary of the Washington delegates, delays in issue of minutes and the consequent difficulties arising from such delays.
Action 17-2 Col. Thatcher Mr. Drake Brockman	To discuss, and agree on the boundaries between, the areas of interest of their respective panels.
Action 17-3 Secretary	To amend Paper NWLC/P(64)2 in accordance with directions of Committee, for transmission by the Chairman to Chief Scientist M.O.D. (Army), as an expression of the Committee's views on the future use of the Suffield site.
Action 17.4 Secretary	To express to T.I.L. the Committee's appreciation of the work done in preparation of the bibliography of references, supplementary to ... Plans Note 45.
Action 17.5 Mr. Hendricks	To write to ...W.R.E. to hasten completion of Antler and Buffalo reports.

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20

L.H. 13E

Telegrams: Avmin, London, Telex.
Telex No.: 22241.
Telephone: Museum 3644.

Extn. 238

Your Reference SAN 19/7/1

Our Reference XY/306/01

MINISTRY OF AVIATION,
Room 840,
ST. GILES COURT,
1-13 ST. GILES HIGH STREET,
LONDON, W.C.2.

23rd July, 1964.

Dear Mr. Pavry,

I write in reply to your letter of 2nd July, to Mr. Garrard, referring to the E.M.P. aspect of the Seminar to be arranged by Group Captain Chettle. I enclose a 'Tentative Agenda' for this, which you will see, is headed " - with particular reference to Air Force Equipment and Installation."

This meeting is expected to cover all effects, including E.M.P., with special reference to Air Force problems. It is proposed that further Seminars of this type should be arranged to meet the specific interests of other Service Departments. You are therefore invited to rough out a similar tentative agenda covering Home Office and Civil Defence problems in the same way, and to include names of persons whom you would wish to attend, as you have done with Mr. Hurst.

It is anticipated that such a Seminar to meet your requirements could be held at the Home Office. You will see that no date has yet been fixed for the Air Ministry meeting, but this should take place during the last two weeks of September. You may therefore assume that some time in October could be arranged for the Home Office meeting.

Please let me know if I can be of any assistance to you with these arrangements.

Yours sincerely,

Margaret Wilkie

M. E. WILKIE
Secretary, Nuclear Weapons Lethality Committee.

Mr. F. H. Pavry,
Home Office,
Scientific Advisers Branch,
Horseferry House,
Dean Ryle Street,
S.W.1.

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XY/356/01.

Proposed Symposium at M.C.D.(Air Ministry) on INTERPRETATION OF NUCLEAR WEAPON EFFECTS with particular reference to Air Force Equipment Installation

TENTATIVE AGENDA

1. Purpose of meeting. Introduction by Group Captain P.M.Chettle.

2. Effects

   (a) Blast

   (b) Thermal Radiation

   (c) Nuclear Radiation

   (d)(i) E.M.Pulse

   (ii) Currents and Voltages derived in systems

   (e) Synthesis

3. Target Response.

   (a) Thermal and Blast

   (b) System Effects

   (c) Biomedical.

4. Application of Work on Nuclear Weapons Effects.

   (a) Relevance to the work of the Air Force Department on behalf of D.C.A.S.

   (b) Existing Studies - (Staff of) So.2.Air Min.

5. Terms of Operational Requirements (Staff of, Oper.Reqts. Air Min

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NOTES ON TENTATIVE AGENDA — Estimate of Time

ITEM 1. - Group Captain Chettle.
Introduction and purpose of symposium — 5 minutes.

ITEM 2. - (a) Blast Effects — 10 minutes

Essentially the phenomena associated with the blast wave in air. Ground reflection, mach stem and [illegible] effects only significant for case of items on or near ground. Detail therefore required on over pressure, dynamic pressure and wind velocities, as modified by yield and altitude. The effects up to 10-20 p.s.i. only need be covered.

(b) Thermal

Estimate of Time

Indication of protective measures likely to be effective.

(c) Biomedical Effects — 10 minutes

Hazards to personnel onthe ground and in aircraft from combined effects. Assessment of critical hazard to man in operational situations. Indication of protective measures likely to be effective.

ITEM 4.

(a) Relevance to work of Air Force Department — 10 minutes

The senior representative of the Air Staff present will show the relevance of these studies to the task of the R.A.F. and instance any particular areas of concern to the Staff.

(b) Existing assessments of hazards — 10 minutes

This item is included to show the results of work already completed in this field, so that a better estimate of the effort required and the method of attack can be made.

ITEM 5

Terms of Operational Requirements — 30 minutes

This is envisaged as a discussion on the extent to which protection against the hazards, as assessed above, can and should be specified in operational requirements.

19

SAN 19/7/1

2nd July, 1964.

Dear Derrick,

I enclose a copy of a note I have sent to Mr. Sargeaunt about the proposed seminar.

When you come to the stage of issuing invitations would you let me know?

I was with my colleague on the Inter ad hoc group on the day following your meeting. While discussing the Paris discussions - which he missed - [illegible] came up, and so I told him of the proposed seminar. He was very interested, so I said I would ask you to put him on any list you may be preparing. He is:- C. [illegible],
Senior Electrical & Mechanical Engineer,
D.W. 5 Section (Polaris)
H.Q. of Naval Building and Works
Room 1414 Princess Louise Building
Lillie Rd., S.W.6.

Yours sincerely,

F.H.Pavry

D. J. Garrard, Esq.

A.W.D.
Min. of Aviation
St. Giles Court

(Copy sent to Mr Hurst)

Copy sent to Sir Walter Merton Mr Firth Mr Brooker

SAN 19/7/1

Mr. Sargeaunt Discussed F&P

Electro-magnetic Effects

At a meeting of the Nuclear Weapons Lethality Committee on June 30th, this subject was discussed, following a statement by Mr. Garrard on his recent visit to America. Group Captain Chettle, A.D./A.W.D.2, said he proposes to organise a Seminar at which designers and users of equipment could discuss their problems with the experts in the E.M. effects.

I requested that the Home Office Communications Branch and the G.P.O. should be included in the list of invitations, and this was agreed by the Chairman, Mr. L. T. B. Williams.

This would seem to be the best way of getting the information to the people who need it, and I will keep in touch with Mr. Garrard about attendance. (We shall also include Power interests.)

I would expect that the proposed Seminar, if it is to take place reasonably soon, could replace the discussion between Mr. Garrard, G.P.O. and Communications Branch that was proposed at the meeting in your room on April 16th.

F.H.Parry

2nd July, 1964.

Scientific Adviser's
Branch.

Copies to Sir Walter Merton, Mr. Firth,
Mr. Garrard , Mr. Brooker

SAM 19/7/1

Mr. Sargeaunt

Electro-magnetic Effects

At a meeting of the Nuclear Weapons Lethality Committee on June 30th, this subject was discussed, following a statement by Mr. Garrard on his recent visit to Norton. Sir Harold Roxbee Cox, K.B.E., C.B., said he proposed to organise a seminar at which designers and users of equipment could discuss their problems with the experts in the E.M. effects.

I requested that the Procurement Executive Communications Branch and the R.A.F. should be included in the list of invitations, and this was agreed by the Chairman, Mr. L. T. B. Williams.

This would seem to be the best way of getting the information to the people who need it, and I will keep in touch with Mr. Garrard about attendance. (We shall also include Power interests.)

I should suggest that the proposed seminar, if it is to take place reasonably soon, could replace the discussion between Mr. Garrard, Mr. [illegible] and Communications Branch that was proposed at the meeting in your room on April 16th.

2nd July, 1964.

Scientific Adviser's
Branch.

Copies to Sir Walter Merton, Mr. Firth,
Mr. Garrard, Mr. Brooker

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Whitehall, LONDON S W 1
Telegrams: Monebus Parl London
Telephone: WHItehall 8100, *ext.* 332.

Please address any reply to
THE UNDER SECRETARY
OF STATE
and quote:
Your reference:

15.6.64

Dear Barney,

I have had a few telephone calls recently on this matter and you may wish to have this copy letter I'm not sure how far Lloyd has got with the committee arrangements for I sent him our file

Yours sincerely

J. Hunter

J. St Barney Esq

SG

CONFIDENTIAL

47A

GPO

Inland Telecommunications
Department
Headquarters Building
St. Martin's-le-Grand
LONDON EC1

Telex: 21166 (PO HQ LDN)
Telegrams: Gentel London EC1
Telephone: HEADquarters 4564

In any reply please quote:
Your reference: COM64.71/4/1

12 June, 1964.

Dear Brooker,

In my letter of the 8th May I mentioned that I would bring up the question of the effects of electro-magnetic flash upon electrical plant at the next meeting of Committee L and that I would let you know of any developments. The meeting was held on June 4th and we had a fairly brief discussion on the subject. Col. Brandle, who was in the Chair, accepted the views which I expressed to you in my letter of the 8th May and promised that the Ministry of Defence would initiate action, probably through CCC, to have this question looked at again. He did, however, quote from a report by Messrs. Abercrombie and Iston, of AWRE, which painted a rather more reassuring picture than that given to ~~him~~ me by Squadron-Leader Linthwaite of RAF Home Command. I have not got a copy of this report and I should be grateful for a sight of it if you can lay your hands on a copy in Home Office.

I am copying this letter to Haworth of the Engineering Department.

Yours sincerely,

K Ford
(K. FORD)

J. L. Brooker, Esq.,
Communications Branch,
Home Office,
Whitehall,
LONDON, S.W.1.

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/6

THE QUEEN'S UNIVERSITY OF BELFAST

PROFESSOR K. G. EMELEUS
TELEPHONE: BELFAST 30111

DEPARTMENT OF PHYSICS,
QUEEN'S UNIVERSITY,
BELFAST 7,
NORTHERN IRELAND

CONFIDENTIAL

6th June, 1964.

Full 6/6

F. H. Pavry, Esq.,
Home Office,
Scientific Advisers Branch,
Horseferry House,
Dean Ryle Street,
LONDON, S.W.1.

Dear Mr. Pavry,

Thank you very much for your letter of June 4th, which arrived this morning. It looks as if we cannot do anything but take more or less standard precautions for the present and I will advise our friends at Stormont to this effect.

Thank you also for your personal message. I hope we may have a chance to show you our building some time in the future.

Yours sincerely,

K. G. Emeleus

SAN. 19/7/1
62

531

4th June, 1964

Dear Professor Emeleus,

As Mr. Sargeaunt is abroad, I am replying to your letter of May 23rd.

We have been doing our best to get the kind of information you want, but have had only very limited success so far. We did manage to arrange for engineers from our Communications Branch to attend a meeting in March, when some Americans specialising in the problem called at Aldermaston. The general impression conveyed was that devices that give good protection from lightning flashes should protect from electro-magnetic pulse, but the wave front of the pulse is much faster than that of the lightning flash; so care must be taken with transistors, and "protector blocks" need to be at closer intervals. There seems to be an obvious case for protectors that will reset themselves when they have been triggered, and for this reason neon lightning protectors were mentioned as being effective. The Americans at the meeting promised an unclassified report on research to date, and if we can get hold of this we will let you have a copy.

We too, in close touch with the Ministry of Aviation representative on the Anglo-American research team, and have from time to time brought in communications and power specialists to ask the right questions.

/ It seems ....

Professor K. G. Emeleus, MA, Ph.D., Sc.D., MRIA,
Professor of Physics,
Queen's University,
Belfast.

CONFIDENTIAL

It seems that this is a most difficult field to cover so long as the test ban is in force. One thing we can be sure of is that no effort or expense will be spared on the research, as it is of even more vital concern to the offensive side than it is to us. Our Communications Branch is now discussing with the Post Office the implications of the information available to date. If anything practical comes out of this we will see that you hear of it.

It was a pleasure to meet you and your wife while we were staying with Miss Herdman at Dunmurry. It was very kind of you to offer to show me the University, but I took you at your word that you would not mind if I did not take advantage of the offer: the Northern Ireland weather held good for the whole of our stay, so we made the most of it seeing the country.

Yours sincerely,

F. H. Perry

14
80

THE QUEEN'S UNIVERSITY OF BELFAST

PROFESSOR K. G. EMELEUS
TELEPHONE: BELFAST 30111

DEPARTMENT OF PHYSICS,
QUEEN'S UNIVERSITY,
BELFAST 7,
NORTHERN IRELAND

Secret

23rd May, 1964.

H. A. Sargeaunt, Esq., C.B., O.B.E., B.A.,
Scientific Adviser's Branch,
Home Office,
Horseferry House,
Dean Ryle Street,
London, S.W.1.

Dear Sargeaunt,

Some two years ago a little information was circulated verbally about supposed effects of atomic bomb explosions on transmission lines and telephone lines. It was not to the best of my recollection at all definite, and probably came from the United States.

We have been able to trace nothing about it since. The gist of what was mentioned was that large surge voltages might be induced on transmission lines which could produce serious effects not only close to the position of the bomb burst but also at distances of very many miles (say 50). It was and is not clear to me whether these surges were only on live power lines, or whether they also occurred on power lines which were not live at the time of the burst.

Anything of this kind could be serious for us here for two reasons: first, it could put out of action transformers and switch gear, and, second, possibly even more important, surge voltages might be produced directly or by induction in telephone lines and put out of action vital telephone exchanges.

If we knew whether all this is likely to be of significance we might, even at this stage, be able to introduce extra protective devices or alter some of our telephone routing and communications, and we would be very grateful for any help that you can give us.

p.t.o.

It would of course be essential for the main facts to be available to at least Dennis and Montgomery at Stormont. and this letter is in fact sent at their request.

With kind regards,

Yours sincerely,

K S Gracey

KSG/CWS.

HOME OFFICE
Whitehall, LONDON S W.1
Telegrams: Monebis Parl London
Telephone: WHItehall 8100, *ext.* 332

Please address any reply to
THE UNDER SECRETARY
OF STATE
and quote: COM 64 71/4/1
Your reference:

11 May 1964

Dear Stanbury,

I am sending you a copy of this letter from Ford without being able to refer to the note I sent him, but this letter is self contained. I have no doubt at all that, up to the present, information on E.M.F. has been too hole in the corner and I personally think that the matter should be up with the official committee on communications / Elections so that all interested Departments can know what is going on and be kept advised of the latest

latest appreciations.

This reminds me that we were to have an informal meeting with GPO and friends of MJA when he would get some good information from Alderman. Clearly Garand was unable to get what he wanted in the two or three days he'd hoped: do you know how we stand for a meeting in June?

Yours ever

JEBrooks

J R Stanbury Esq
SAB

Restricted.

12

Tony
Coy/64 21/4/1

GPO

Inland Telecommunications
Department
Headquarters Building
St. Martin's-le-Grand
LONDON EC1

In any reply please quote:
Your reference:

Telex: 21166 (POHQ LDN)
Telegrams: Gentel London EC1
Telephone: HEAdquarters 4564

8th May, 1964

Dear Brooker,

Thank you for your letters of the 17th and 20th April on the question of possible damage to equipment resulting from electro magnetic flash and radiation. I was very interested in the information you provided and I have talked the matter over with Hill and with senior members of the Engineering Department. It is our view that this matter goes well beyond communication questions and that in fact we should expect some central body, such as the scientific staff of the Ministry of Defence, to acquire the basic research information on the electro-magnetic and radiation effects of nuclear explosion on electrical plant of all types. We should expect that they would make this information generally available to Departments with defence interests with the request that those Departments used the information as the basis for further research on the plant for which they were specifically responsible. On this basis the Ministry of Power would consider the effects on generating stations and transmission lines and we should consider the effects upon communication equipment. But we do not feel that it is up to us in the Post Office to undertake research in this matter without central Government guidance. Indeed I am advised by my engineering and scientific colleagues that we could not do research in this matter unless we were supplied with the basic data.

The crux of the matter seems to be whether or not Ministry of Defence is taking an overall look at the problem. If they are not then I think we ought to stir them up and I propose to raise this matter at the meeting of Committee L of the Defence Signals Board on 4th June. I will let you know what their reactions are.

I am copying this letter to Haworth of the Engineering Department.

Yours sincerely,

K. Ford

(K. FORD)

J. L. Brooker, Esq.

With the Compliments

of the

Director of Communications

Communications Branch,
Home Office,
Whitehall,
S.W.1.

MH

Copy for the information of, Mrs Pavry
Scientific Advisers Branch, Horseferry House,
LONDON S.W.1

COM/64 71/4/1

20 April, 1964.

Dear Ford,

Mr. Flach

You will remember I rang you on 25th March to tell you that the talk given the previous day by the Bell laboratory telephone man Jack Biddaugh was most interesting, although he had excused himself that it had been bounced on him at very short notice and I suggested you might get in touch with Pavry with a hope of seeing him before he returned to Paris. In the event I found when I returned from sick leave that this had not been possible.

Muldaugh

I had intended since the talk to put my notes in better order by my copies of the diagrams and graphs (that Biddaugh himself drew freehand) I find hardly merit their copying; particularly as we were promised that all this was about to be published as a paper and that would arrange the proper distribution (it could be that something will appear in the Bell Journal).

I am prompted to write this note as a result of a meeting in Horseferry House today where Garrard (Ministry of ~~Health~~) gave his account of the talk supplemented by some most useful background information.

The general conclusion after the discussion was that rather than wait for this paper of Biddaugh's to

/be

K. H. Ford Esq.
I.T.D. (P.E.)
G.P.O.
LONDON E.C.1

CONFIDENTIAL

be published the G.P.O. should be invited to a similar talk/discussion after Garrard had checked certain figures, graphs and formulae with Abercromby of [illegible]. Garrard had copied down, (rather better than I), the information given but we cannot make sense of all of it. Garrard thinks he can either get what he wants in a couple of days or he will have to wait till late May. Could you accept this as advance notice of an invitation for say a fortnight's time or sometime in June?

I may not have this in very logical order but now to give you my idea Middaugh's conclusion: lightning flashes of greater currents have been measured, but the wave front electromagnetic flash is much shorter than lightning therefore care must be taken with transistors and "protector blocks" need to be at closer intervals. Overall I formed the opinion that if action for protection was taken as in a high lightning area so long as proper regard to the sharp wave front was given this would be satisfactory. Middaugh had a good opinion of B. T. H. neon type lightning protectors.

Finally we have it that there has been a change in your policy on protection against lightning and would welcome an assurance that it does not lessen protection against this E.M.Flash. hazard.

Yours sincerely,

J. B. Smith.

CONFIDENTIAL

Sir Walter Merton

Electromagnetic Effects

When I came recently to discuss this problem with you I said I would let you know when any new information came our way.

We heard recently that representatives of the U.S. Bell Telephone Company were coming over for discussions at Aldermaston, so I arranged for Mr. Watson and Mr. Rosher, both of Communications Branch, to join them in a meeting there.

Mr. Watson and Mr. Rosher agreed to report to us, so I have arranged a meeting at a time which I understand from Miss Packard suits you: 11 a.m. on Thursday the 16th April.

I expect we will meet in Mr. Beaumont's room, and I hope that Mr. Barrard, of the Ministry of Aviation, who is one of the experts in this field, will also be coming.

I understand that we cannot expect to hear of any great advances as a result of the Aldermaston discussions, but the meeting on Thursday should be useful and interesting.

F.M.Savry

13th April, 1964.

Scientific Adviser's
Branch.

Abercrombie Radio 55811 General Aviation
ext 7966. Green } RAE.
Ramsay }

Meeting with Bell Telephone engineers
on Tuesday 24th at 2 p.m.
Room 120 Building C11 AWRE
Aldermaston

Mrs Wilkie Awkins Museum 3644 x 238.
Informed AWRE Brocken was taken to attend
meeting

CONFIDENTIAL

Sir Walter Morton

Electromagnetic Effects

[illegible] to reply to [illegible] query.

It is true that the electromagnetic pulse emitted at the explosion of a nuclear weapon can, in general, affect all kinds of communication and power networks; and that adverse effects are not limited to the very high air bursts.

The very high bursts over the Pacific were carried in the name of 'The Effects of Nuclear Weapons', and it will be seen that some, [illegible] and other devices were 'blacked out' for several msec. (These measurements [illegible] are duly recorded in the technical journals soon after the tests.)

We have also had some details of the electromagnetic effects of [illegible] and post-[illegible] events at the Nevada test site; they were to [illegible] of the U.S. Congress Committee on Science, rather than the Committee of Inquiry; and the information supplied to [illegible] was installed, it was to a large extent successful.

The [illegible] of the [illegible] under consideration is [illegible] mechanically [illegible]; [illegible] events, and [illegible] to-[illegible] [illegible] to [illegible] they [illegible] of [illegible] in [illegible]. We [illegible] to [illegible] have a close contact with a member of the [illegible] team, and we are kept informed of the state of the research from time to time.

We have brought it to the discussions the [illegible] [illegible], [illegible] other [illegible] [illegible] the [illegible] of [illegible], we [illegible] [illegible] of the problems. [illegible] [illegible] [illegible]; it was felt [illegible], that a lecture by the [illegible] member, in the case of the R.S.A's.

The [illegible] be summarised by saying that there is certainly a risk to [illegible] [illegible], but that it is not [illegible] [illegible] [illegible] that for the events to [illegible] the risk is, or what can be done about it.

[illegible] we do not expect that the cost or cost will be [illegible] in the event to get the necessary [illegible], since it is [illegible] [illegible] the wide field of active [illegible] [illegible].

[illegible] to point in time, that the [illegible] [illegible] [illegible] class [illegible], and that is why I have marked this [illegible] 'Confidential'.

If you wish to see the [illegible] [illegible] of the [illegible] the subject, or would like to discuss it, will you please let me know.

F.H.Pavry

5th February, 1964.

Scientific Adviser's Branch
Home Office.

I also spoke to the I.G. about this and said I would arrange for Cawood to have a talk with him next Time he is over here

FHP 5/2

CONFIDENTIAL

8

Mr. Sargeaunt

I understand that there is a possibility that a high Nuclear explosion might, as a result of induction, put all forms of communications landline, radio and W.T. out of action. I also understand that it is possible that it might put all power stations, not damaged by blast and fire, out of action by burning out generators.

As this is alarming, I would be grateful for a very brief statement of the facts.

28th January, 1964

(W. MERTON)

Copy to: Mr. Graham Harrison
Mr. McConnell

7

531

SAN 19/7/1

12th March, 1963.

Dear Carrard,

I ran a few days ago and heard that you are away for a few weeks.

On your return, would you let me have any information about the expected visit of the man from Bell Telephones? During a recent talk with one of our Terminal Wireless Engineers I heard that the C.A.C.E. establishment at Heathrow have been doing research on induced effects from lightning flashes. I expect you know about this, but I felt I should pass on the statement, just in case it is of interest.

Yours sincerely,

F.H.Lavry

D. J. Carrard, Esq.
A.W. Plans,
Ministry of Aviation
St. Giles Court
W.C.2.

NOTE: This is summary of B. J. Stralser's report of 30 April 1961, "Electromagnetic Effects from Nuclear Tests", DASA-1226, E.G.G. report L-523 (68 pages), SECRET

A64/XY/222/05 6

CONFIDENTIAL DISCREET XY/222/05

Some Observations of Electro Magnetic Flash Damage resulting from Nuclear Explosions

The information presented below has been acquired incidentally during nuclear weapon tests, when instrumentation has been designed to record other effects, and is therefore mainly empirical. Awareness has nevertheless grown that electro-magnetic radiation can cause severe damage or operational disruption in all kinds of electrical systems.

Electro-magnetic radiation from a weapon encompasses a very broad band of radio frequencies and can induce large voltages, and currents in conductors and circuits, even when they are remote from the explosion. Complex control circuits and communication and power lines represent large antennae in which disturbing signals are induced by the radiation and are particularly vulnerable, and damage can occur many miles from the explosion.

The examples quoted here are limited to observations made by the personnel of Edgerton, Germeshausen and Grier during test series from 1951 to 1958. The charts summarize damage under the categories of

1) Damage to Signals Systems

2) Damage to Power Systems

3) Damage to Systems using Earthing and Screening protection.

4) Miscellaneous Damage.

Examination of the data shows that while, in general, damage increases with the yield of the device, and air and balloon shots are more damaging than tower or underground shots, it is not possible to correlate effects directly with either yield, type of device or height of burst. Moreover, while a typical pattern of damage can be observed where extensive cable lines exist, so that probable sites of damage can be indicated, the induced voltages nevertheless tend to build up in an unpredictable manner, similar to a lightning strike. An example of this is the violent explosion at a conduit entrance 13 miles from G.Z. with no recorded damage to the intermediate signals system.

As would be expected, the lighter conductors used in signals systems showed more serious damage than power lines, but the effect was transmitted to greater distances by the heavier cables, causing circuit breakers to trip at distances of over 30 miles from G.Z. Damage to equipment at intermediate stations could be catastrophic in either case.

A point not apparent from the damage summaries should be noted in respect of telephone communications. The contractors state that it was found necessary to remove the commercial type carbon blocks for voltage surge protection, since these were found in most cases to fuse or weld together, short-circuiting the signal. Jumpers were substituted in their place.

Protection against anticipated effects was employed only in the case of certain equipment, in which extensive earthing and screening devices were used, and these were to a large extent effective. The danger to electronic equipment, however, is shown by the random malfunctioning of the counting unit, controlling timing of camera shutters. This effect was subsequently repeated by an experimentally induced electric field, confirming the cause of failure. It is generally clear increased sensitivity of equipment implies increased vulnerability to electro-magnetic effects, and that protection of oscilloscopes is necessary to avoid obliteration ('blooming') or distortion of the signal.

Actual measurement of an induced voltage is shown in only one example, where approximately 3250 volts was recorded by a galvanometer, protected by a 10,000 volt air gap, inserted in an unconnected 5½ miles length (paired) of timing signal lines, running from within ½ mile of G.Z.

Damage to Signals Systems

Typical

Distance from G.Z.

1560'	½ mile	2½ miles	5½ miles	17 miles
Connection Box Invariably blown or fused	Timing Distribution Station Meters, relays burned out. Terminal strips melted	Timing Stations Meters, potentiometers, relays destroyed. Panel lights burned out.		Control Point Meters, Relays burned
Cables fused Insulation breakdown	Cables fused Insulation breakdown	Cable insulation damage	Cable insulation damage	

Examples

Yield	Type and Height of Burst				
Over-nominal	Tower 700'			2½ miles Timing Stn. 6 meters and potentiometers, 3 relays destroyed.	17 miles Control Pt. 2 meters destroyed
Sub-nominal nominal and over-nominal	Series of balloon shots No height given	1500' Connection box for balloon signal cable destroyed.	½ mile Timing Distn. Stn. Insulation destroyed Conductors fused together.	2½ miles Timing Stn. Insulation breakdown on cables.	
Nominal	Tower 500'		3500' Timing Distn. Stn. Random malfunction of indicators		
Nominal	Air 524'			2½ miles Timing station Random malfunction of indicators	
Sub-nominal	Series of Balloon shots No height given	1500' Connection box for balloon signal cable destroyed	½ mile Timing Distn. Stn. Cables to sub-station and Timing stations damaged.		
Not given	Series of Tower shots No height given	1500' Suppression box Capacitors destroyed	½ mile Timing Distn. Stn. Relays burnt out		
Nominal	Air 6020'			3 miles Telephone relay stn. Carbon contacts fused. Conductors fused in cables on far side.	
Over-nominal	Tower 300'				13 miles Control point Explosion at conduit entrance. Lead sheathing evaporated
Not given	Underground Series		about 1 mile Signal cables fused in underground tunnel		

Damage to Power Systems

Typical

Distance from G.Z

1000'	3000'	3 miles	12 miles	30 miles
Portable sub-station	Power distribution Station	Power distribution station	Control Point	Power station
Fuses blown, arcing across insulation.	Fuses, blown, arcing across insulation. Short-circuiting across transformer windings. Arcing to transformer case.	Oil circuit breakers tripped		Oil circuit breakers tripped

Pinhole damage to cable insulation, near to sub-station

Cable insulation damage

Examples

Yield	Type and Height of Burst	
		½ mile. Experimental cages; ½ mile radius from G.2.
Over-nominal	Tower 300'	Cables buried 18" depth. All destroyed by pinholes in insulation.
Nominal	Tower 300'	1000' Sub-station and power stations; 6' underground. Cable between stations destroyed. Transformer primary fused, and arced to core.
Not given	Underground series	about 1 mile, underground tunnel. Insulation damage, by charring, to power cables.

Damage to certain Systems in which extensive Earthing and Screening was used

Yield	Type and Height of Burst		Distance from G.Z.
Not given	Series of Tower and balloon shots		Station at 3000 ' Resistors destroyed
Over nominal	Tower 500'		Station at 3000' Oscilloscope exploded
Nominal	Tower 300'	1000' Station 6' underground. Transformer primary fused, arcing to core.	2 miles Photographic recording station. Electronic counting unit. Malfunctioned in random manner.
Not given	Series of Tower and balloon shots		Station at 3000' Pins of rectifiers in oscilloscopes burned off. Glass envelope shattered in most cases. 6 x 4 type rectifiers.
Nominal	Tower 500'		11 miles Oscilloscope with photo-multiplier, for light analysis (unscreened) "Ball-of-yarn" distortion of trace.
Not given	Underground Series		about 1 mile, underground tunnel Breakdown of cable insulation, burned spots for 50 feet.

Miscellaneous Damage

Yield	Type and Height of Burst	Distance from G.Z.	
Nominal	Balloon 1500'	3 miles 1000 feet length of 4-conductor, 6000 V cable, on reel, unconnected. Pinhole damage to insulation along complete length.	600-V cable
Nominal	Tower 300'	3000' 1000 feet length of single-pair wire, on surface, unconnected. Draped over station building. Burning at end touching metal plug in wall, 3" burning on wall, melting of wires for ⅛".	
Nominal	Balloon 1500'	5½ miles Galvanometer recording of 3250 volts induced in timing signal lines, unconnected, running from timing distribution station at ½ mile from G.Z.	

Our: SAN 19/7/1
Your COM 203/24/1

Induced Voltages in Cables.

Dear Brodcer,

With regard to your letter on this subject, ~~I understand that this it is there is only one person in this country who~~ we rely on Garrard for guidance, and Parry consulted him before replying to the limited query in your letter of 27.10.'59.

I ~~understood~~ gather that the whole business of the effects of the electromagnetic pulse on communications is still far from being properly understood, and that the Americans have a major research programme in hand. We have done what we can to keep your Branch in touch with any results that Garrard may have: for example, Watson attended meetings on this subject in March & December last year, and at the second meeting we brought in Merriman of the Post Office.

I see no reason at this stage to dismiss the hazard as unimportant. The implications go far beyond the problem originally raised by you: the personal risk to a ~~pers~~ man ~~holding~~ using a telephone. If, for example, conventional devices for surge protection ~~were~~ are operated by a nuclear explosion over a large area of the country, this could surely be a very serious matter.

You have, presumably seen Garrard's paper that we sent to Watson on April 4th, '62. It is clearly stated there that one type of commercial surge-protection device was affected 'in most cases' and another type had to be used instead.

E L W

Please Brodcer on the lines of the above.

5/3/63

HOME OFFICE
WHITEHALL, LONDON S.W.1
Telephone Whitehall 8100 *Ext.* 332

Our reference: COM 205/24/1
Your reference: SA/N - 19/3/1

Dear Leader

At this morning's meeting it was left with Thompson of POly Dept was left with the job of preparing a note on induced voltages from nuclear explosions. I had a little note from Parry on this on 6 Nov '59 and was assumed also by other people in GPO at that time that this hazard had been

been made much of it. So I dropped it.
I now hear to have the score has popped up
and last autumn Blair here spoke to
Parry who put him on to Garrard
Mins of Aviation.

Give send Thompson a copy of Hendon's
Blair made by Hewitt Garrard which
talking inward voltage about $\frac{10^7}{n}$ for unit light

'i'.

Im afraid Ive been so condemned since
last I views this alleged legend with the
gravest doubts. Could you please add either
Thompson a myself on a line?

Yours sincerely
H Brooker

Mr. R. Firth

Electromagnetic Effects of Nuclear Explosions

You sent me a minute on this subject on the 2nd November.

We had a meeting with Mr. Garrard of DGAW, Ministry of Aviation, about 9 months ago prior to his leaving for the U.S. to participate in the "Small Boy" trial in Nevada in the Summer. Mr. Garrard was in Washington again recently to attend a symposium on 13/14th November at which some of the results of the trial were discussed, and a brief note of this meeting is attached.

We have now had the opportunity of meeting Mr. Garrard again together with representatives of Communications Branch and the GPO and hearing some account of this work. While very interesting scientifically it is obvious that at the present time there are so many unexplained anomalies that it would be quite impossible to recommend any particular course of action until we have further information.

A representative of the Bell Telephone Company - one of the major contractors in the trial - will be in this country soon and we shall take the opportunity of talking to him. In the U.S. a large body of experts has been recruited to try and make some sense of the results, and I doubt very much whether we shall hear anything more before the Summer at the earliest. In the meantime Garrard will be working on his own results and will let us have a copy of his report as soon as it is ready.

My general feeling is that the normal precautions that are taken against lightning ~~both~~ in communication circuits ~~and in power lines~~ will be a partial safeguard for communication circuits and that more thought is required as to what should be done for power.

SARGEAUNT

Chief Scientific Adviser
4th January, 1963.

I hope after the "Bell" meeting that I shall not have to be so negative.

S E C R E T

Direct

Ref: XY/398/01

NWLC/P(62)12

JOWOG-6
D.A.S.A. Symposium on Small Boy Event
Programmes 2, 6 & 7

Introduction

Through U.S./U.K. Joint Working Group No.6, we were invited to participate in a Symposium held at the National Bureau of Standards, Washington, on 13th and 14th November, 1962. At this symposium all available data were presented on the following experimental programmes of Small Boy:-

Programme 2 - Measurement of Neutron and Gamma Doses and Dose Rates.

Programme 6 - Electric and Magnetic Field Measurements, Air and Soil Conductivity.

Programme 7 - Electromagnetic Flash Target Response Measurements.

Items included in these programmes are listed in NWLC/P(62)7.

The remainder of the 88 Items of the Small Boy programme were excluded from this Symposium. The effects of nuclear radiation on electronics had been covered in a recent DASA TREE panel meeting.

A.W.R.E. were invited to describe the results of their electric field and air conductivity measurements, and in the course of the symposium the Ministry of Aviation representative was asked to describe his magnetic measurements. The programme of the Symposium, with subjects of individual contributions, is given in the Agenda at Appendix 'A'.

Nuclear Radiation Data

A considerable amount of raw data on the time dependence of the neutrons and gamma radiation, as measured in a variety of ways, was presented by DOFL, NDL, SRDL, EG & G and Northrop-Ventura. Total dose measurements were also reported. The overall impression was gained that the data from different sources only agreed to within an order of magnitude at this stage, and that there was yet much work to be done in sorting out the discrepancies, mainly due to instrumentation. Nevertheless the data from Small Boy, although not wholly consistent, represented a considerable increase in our knowledge.

Air Conductivity

As an important part of the attempt to develop a soundly based theoretical approach to the origins and propagation of radio-flash, several measurements of air and soil conductivity as a function of time were carried out by different agencies. These included air measurements by Magnetohydrodynamics Corporation under contract to U.S. Air Force Special Weapons Center and by A.W.R.E., and soil conductivity measurements by the U.S. Geological Survey. The A.W.R.E. measurements were of high time resolution and should represent an important contribution to basic knowledge.

Magnetic Field Measurements

The principal effort was that by DOFL, who measured the magnetic field by integrating the output from small pick-up loops at a number of sites. Despite overloading caused by a fairly late change in the nuclear device used for the test, their measurements were largely successful, and included for the first time measurements 100 ft. below ground. Notes of many of their curves have been made. The Ministry of Aviation contribution, which included the measurement of the peak field pick-up by search coils inside 8 aluminium containers placed at ground level, was associated with this work.

It was reported that the large programme of direct measurements of the magnetic field by Hughes Aircraft Co. had proved abortive.

Electric Field Measurements

The main U.S. effort on electric field measurements was by Boeing Airplane Company. The considerable amount of raw data obtained was reported but will require a considerable degree of interpretation, in view of the nature of the equipment used. The largely successful corresponding measurements by A.W.R.E. were also reported, as were several unsuccessful U.S. experiments.

Effects on Electronic Systems

One of the more expensive programmes at Small Boy, was an elaborate investigation of the currents induced in buried multi-core cable systems. This was performed by the Bell Telephone Laboratories, by Sandia Corporation, by Allied Research Associates for A.F.S.W.C., and others. Measurements were made at a number of places of the wave-form of the induced currents, and peak current indicators were widely distributed. The cables laid included a number of both bare and insulated radial cables, and both large and small cable loops. The aim was to include both basic measurements, and also to give some help in the estimation of the hazard to a particular type of American I.C.B.M. underground installation. Most of the cables were buried about 3ft. below the surface. Although currents up to several thousands of amps. were recorded the currents ranging into tens of thousands of amps which had been anticipated were not found. To this extent the experiments were somewhat reassuring, but it must be remembered that the shot was a small one, and the scaling laws to yields of interest in this application are still open to a moderate degree of doubt. It seems reasonable to expect that some American agencies will wish for a further investigation involving a much higher yield burst.

Results were also reported of measurements at a second shot - Johnny Boy - at which a cable loop completely encircled ground zero. These latter results were limited by instrumental failures, and did no more than indicate that peak valves were consistent with those found at Small Boy.

Reports

The whole Symposium was recorded, and copies of graphs and illustrations were handed in. D.A.S.A. intend to produce a full Symposium record in the next few weeks and U.K. have been promised copies of what should be a most valuable document. As most of the mass of detail was presented in the form of slides and epidiascope projections, note-taking by U.K. participants was extensive but scrappy. Briefings are being arranged for U.K. JOWOG-6 members and others interested in further details.

Conclusions

It is evident that while a surprising number of experiments failed completely, a considerable amount of information has been added to our knowledge of radio-flash and its effects. Nevertheless it is equally evident that this information has not yet been fully digested in the U.S., and it appears likely that the Small Boy event, while considerably advancing our knowledge, will have raised as many questions as it has answered.

There is clear evidence that the fields, even from a very nearly perfectly symmetrical explosion, vary considerably with azimuth, and that the magnitudes of the fields do not at all decrease monotonically with increasing distance.

S E C R E T

This is somewhat disappointing to those of us who hoped for simple answers at an early date.

For our own part we may feel a modest satisfaction that the U.K. participation was very largely successful, and that a definite though limited contribution was made. Contact with the U.S. participants is being maintained, and copies of the final reports of the various participants are expected.

11.62. D.J.GARRARD.

Appendix A

Agenda

DASA Symposium on Small Boy Event
Programs 2, 6 and 7

East Building Lecture Room, Bldg 2
National Bureau of Standards
Washington, D.C.

0900 - 1600

13 - 14 November 1962

CDR W. W. Ennis, USN, Chairman
P. Haas, DOFL, Co-Chairman
Dr. C. A. Blank, DASA, Assistant

Welcome .....Lt.Col. R. W. McEvoy, USA
Introductory Remarks .....General R. H. Booth, USA
Administrative Remarks .....P. Haas

Session I - Environmental Measurements

Dr. L. Wouters, Chairman

Time		Project Title	Project Officer
0915 - 0945	2.1	Gamma Dose Rate	P. A. Caldwell
0945 - 1000	2.3	Neutron Flux Measurements	J. H. McNeilly
1000 - 1015	2.4	Integrated Gamma Dose	R.F. Benck
1015 - 1045	2.2	Neutron Dose Rate	Dr. S. Kronenberg
	6.4	Semirad Initial Gamma Flux Measurements	Dr. S. Kronenberg
1045 - 1100		Coffee Break	
1100 - 1115	6.7	Soil Conductivity Measurements	R. A. Black
1115 - 1130	6.11	Air Conductivity	Dr. M. Jones
1130 - 1200	6.12	U.V. Measurements	Dr. E. D. Draycott
1200 - 1330		Lunch	
1330 - 1350	7.1.4	Gamma Environment	Dr. A. Odell
1350 - 1400	45.9	Neutron and Gamma Measurements	G. Hanson
1400 - 1430	22.1	EG & G Gamma Measurements	M. Knapp

Session II – Magnetic Field Measurements

P. Haas, Chairman

Time		Project Title	Project Officer
1430 – 1500	6.2	Magnetic Loop Measurements	F. Wiminetz
1500 – 1530	6.3	Inherent Magnetic Field Measurements	T. D. Hanscome
1530 – 1545	7.8.1	VLF Loop	Mr. Salton

Wednesday 14th November 1962

Session III – Pragmatic Measurements

Capt. W. Henderson, Chairman

0900 – 0945	6.5	Earth Current Measurements	T. Flanagan F. Schwartz
0945 – 1015	6.6	Cable Loop Measurements	J. Green
1015 – 1045	7.1	Instrumental Measurements	F. Norton R. Buies
1045 – 1100		Coffee Break	
1100 – 1115	7.5	Response of Electric Power Systems	D. E. Dinger
1115 – 1130	45.10	Electromagnetic Radiation Vulnerability	F. J. Weibell
	6.2(c)	Magnetic Measurements	D. J. Garrard
1200 –1300		Lunch	

Session IV – Electric Field Measurements

Dr. J. Malik, Chairman

1300 – 1330	6.1	Electric Field Measurements	W. Nesbitt
1330 – 1345	6.8	Earth's Static Field Measurements	A. Whitson
1345 – 1415	6.9	Correlation of Present and Previous Electric Field Measurements	H. Rono
1415 – 1445	6.12	AMRE Measurements	S.D. Abercrombie
1445 – 1500	7.16	Airborne Electric Field Measurements	LCDR K. Butler
1500 – 1515	45.10	Electromagnetic Radiation Vulnerability	R. Parker

Session V – Panel Discussion and Free-For- All

Dr. C. Longmire, Chairman

1515 – 1615	T	Theoretical Consideration and Comments on the Data

CONFIDENTIAL

Mr. Sargeaunt

I shall be most grateful if the Scientific Advisers Branch could examine the question of whether among the effects of a nuclear burst there is likely to be the overloading of telephone lines with consequent damage to exchanges and subscribers instruments.

We should like to know, if possible, the range at which such damage might be experienced from the ground zero of a nuclear weapon, and the steps, if any which it might be possible to take to neutralise this effect. Whether this effect would apply to the carrier W.B.400 equipment which the Post Office is now installing as a means of distributing warnings. If no satisfactory counter measures can be taken to protect the telephone systems, we would like to examine with Scientific Advisers Branch the problem of the geographical extent to which it might be prudent to arrange for wireless backing.

Finally, perhaps you could give me some indication of how long this project might take and the date by which Scientific Advisers Branch might be able to give us their advice.

K.J.

2nd November, 1962.

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MOD Form 45B

PRO

MINISTRY OF DEFENCE

Registered file number D/407/104/11/10

15 Sept 70 (o)

1. ATTENTION IS DRAWN TO THE NOTES ON THE INSIDE FLAP
2. ENTER NOTES OF RELATED FILES ON PAGE 2 OF THIS JACKET

DIVISION

D. Sc. 6.

FOR REGISTRY USE ONLY

Date opened 17/8/70

SUBJECT

NUCLEAR WEAPON EFFECTS — SYMPOSIUM - DECEMBER 1970.

Referre to	DATE	Referred to	DATE	Referred to	DATE	Referred to	DATE

DCC 7/2491

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Minute Sheet No. : 1 Reference ..... 407/104/11/10.

Minutes and Brief Details of Enclosures	Clas.	Encl. No.
M.1.		
S.W.L.S /550 - C.N° 2 of 3 A.A. 10/12/70. ANRB Programme of Work.	S	23.
M2.		
DEC. 1970. - Min. & E's (Photos) from A.S.W.E. ref XRS 3/9.4/1920/70 - N.W.E. Symposium 11/12/70.	S	27
M3.		
19/4/71 L.M. from D.O.T.E. ref CS 68/506/A2.	S	31.
M4.		
2/70 Report - Collated Papers Presented at the N.W.E. Symposium held on 11/12/70 - C N°250 of 250 ref. 407/104/11/10. 128 Pages.	S	28/1
M5.		
17/11/71 Letter from RARDE ref FCR/872/011 cov. 'Speech notes' - Nuc. Hard. Symp. - Serial 6 (A1) ref S220/71 - C.N° 2 of 7	C/S S	44
M6.		

EMP simulator test of aircraft, Nuclear Weapons Effects Symposium, 11 December 1970 (UK National Archives, DEFE 7/2401)

FIG. 1.

SECRET

4 Conclusion

In the two years since we first started work we have begun to understand some of the problems caused by EMP. A degree of confidence has been gained from this experience, but it is recognised that the greater part of the task lies in the future and there is still much work to be done.

EMP simulator test of tank, Nuclear Weapons Effects Symposium, 11 December 1970 (UK National Archives, DEFE 7/2401)

Figure 1

AWE: SDTN No 3/94

DECLASSIFIED FOR TNA
BY AWE ALDERMASTON
18/1/17

ATOMIC WEAPONS ESTABLISHMENT

DIRECTOR SAFETY AWE

ES21/112

SAFETY DIVISION TECHNICAL NOTE 3/94

A SUMMARY OF THE EFFECTS OF NUCLEAR WEAPONS

A C WOODVILLE

60 381
(IMC 716 360)
924638

June 1994

34220001 234

AWE: SDTN No. 3/94

ATOMIC WEAPONS ESTABLISHMENT

DIRECTOR SAFETY AWE

SAFETY DIVISION TECHNICAL NOTE 3/94

A SUMMARY OF THE EFFECTS OF NUCLEAR WEAPONS

WITH REFERENCE TO THE UK ATMOSPHERIC NUCLEAR WEAPONS TEST PROGRAMMES 1952 - 1958

A C WOODVILLE

Section Leader .....

MHP/PDS (C&DE): T P Maish MSRP

Issue Authorised .....

MHP: G C R Sallit MSRP

Approved .....

D Safety: Dr G Ballard

Director Safety AWE
Aldermaston
Reading
Berkshire RG7 4PR

June 1994

34220004

TABLE 1

UK ATMOSPHERIC NUCLEAR WEAPONS TESTS IN AUSTRALIA

Operation and Location	Date and Time (GMT)	Site	Emplacement	Altitude (m)	Best Estimate of Yield (kt)
HURRICANE Monte Bello, WA	03 10 52 0000Z	Lagoon (12m deep)	Aboard HMS Plym	-3	25
TOTEM Emu Field, SA	14 10 53 2130Z	T1	Tower	31	10
	26 10 53 2130Z	T2	Tower	31	8
MOSAIC Monte Bello, WA	16 05 56 0350Z	G1 Trimouille	Tower	31	15
	19 06 56 0214Z	G2 Alpha	Tower	31	60

34220039

TABLE 1 Continued

Operation and Location	Date and Time (GMT)	Site	Emplacement	Altitude (m)	Best Estimate of Yield (kt)
BUFFALO	27 09 56 0730Z	One Tree	Tower	31	15
Maralinga, SA	04 10 56 0700Z	Marcoo	Ground Surface	0	1.5
	11 10 56 0557Z	Kite	Airburst	150	3
	21 10 56 1435Z	Breakaway	Tower	31	10
ANTLER	14 09 57 0505Z	Tadje	Tower	31	1
Maralinga, SA	25 09 57 0030Z	Biak	Tower	31	6
	09 10 57 0645Z	Taranaki	Balloon suspended	300	25

34220040

TABLE 2

UK ATMOSPHERIC NUCLEAR WEAPON TESTS IN THE SOUTH PACIFIC

Operation and Location	Date and Time (GMT)	Site	Emplacement	Altitude (m)	Best Estimate of Yield
GRAPPLE	15 05 57 1937Z	Off Malden Island	Airburst	2200	0.3 Mt
Christmas Island	31 05 57 1941Z	Off Malden Island	Airburst	2400	0.7 Mt
	19 06 57 1940Z	Off Malden Island	Airburst	2400	0.2 Mt
GRAPPLE X Christmas Island	08 11 57 1747Z	Off SE point of Christmas Island	Airburst	2200	1.8 Mt
GRAPPLE Y Christmas Island	28 04 58 1905Z	Off SE point of Christmas Island	Airburst	2500	3.0 Mt
GRAPPLE Z	22 08 58 1800Z	Over SE point of Christmas Island	Balloon suspended	450	24 Kt
Christmas Island	02 09 58 1724Z	Off SE point of Christmas Island	Airburst	2800	1.0 Mt
	11 09 58 1748Z	Off SE point of Christmas Island	Airburst	2600	0.8 Mt
	23 09 58 1759Z	Over SE point of Christmas Island	Balloon suspended	450	25 Kt

34220041

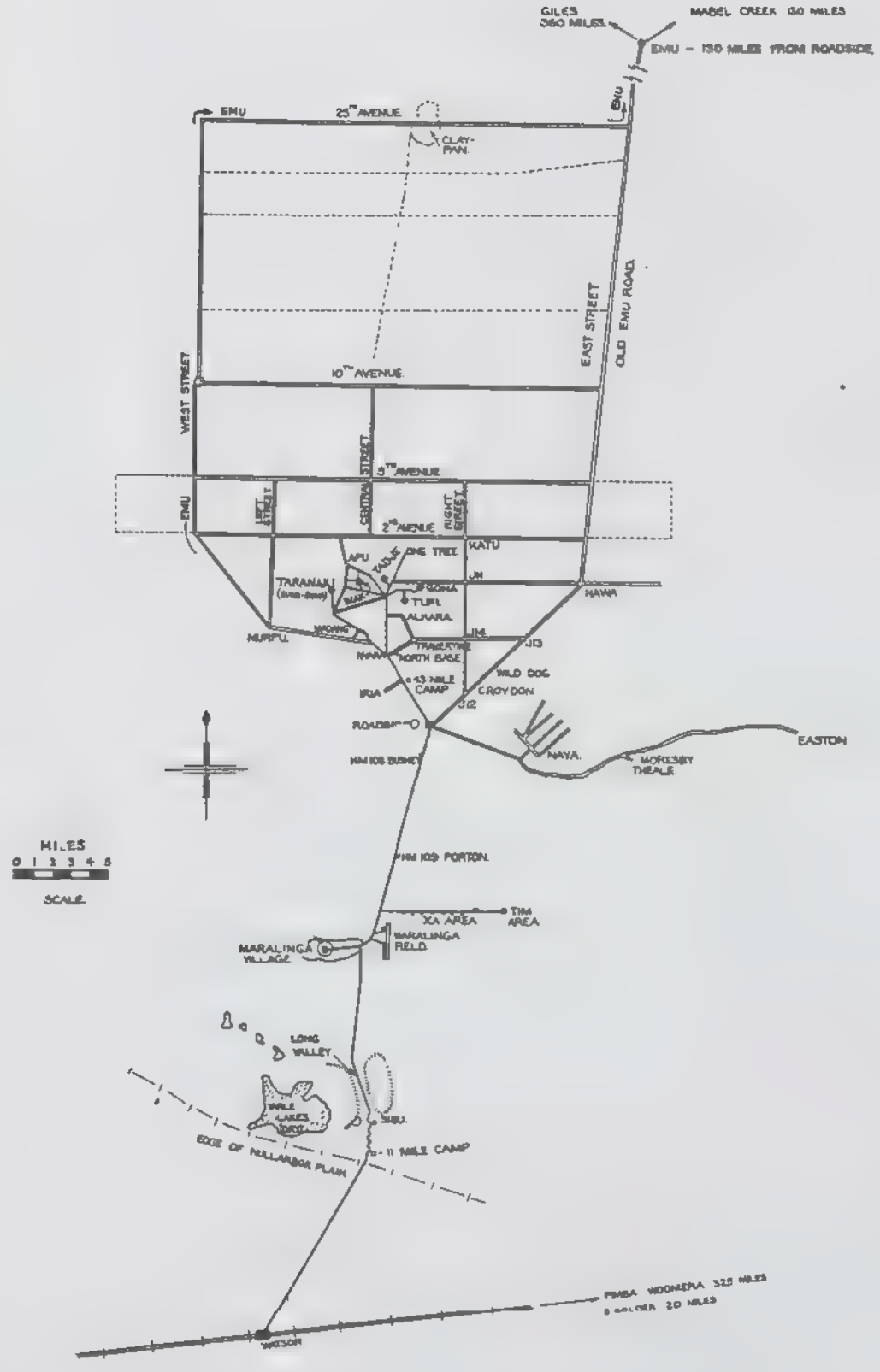

FIGURE 2

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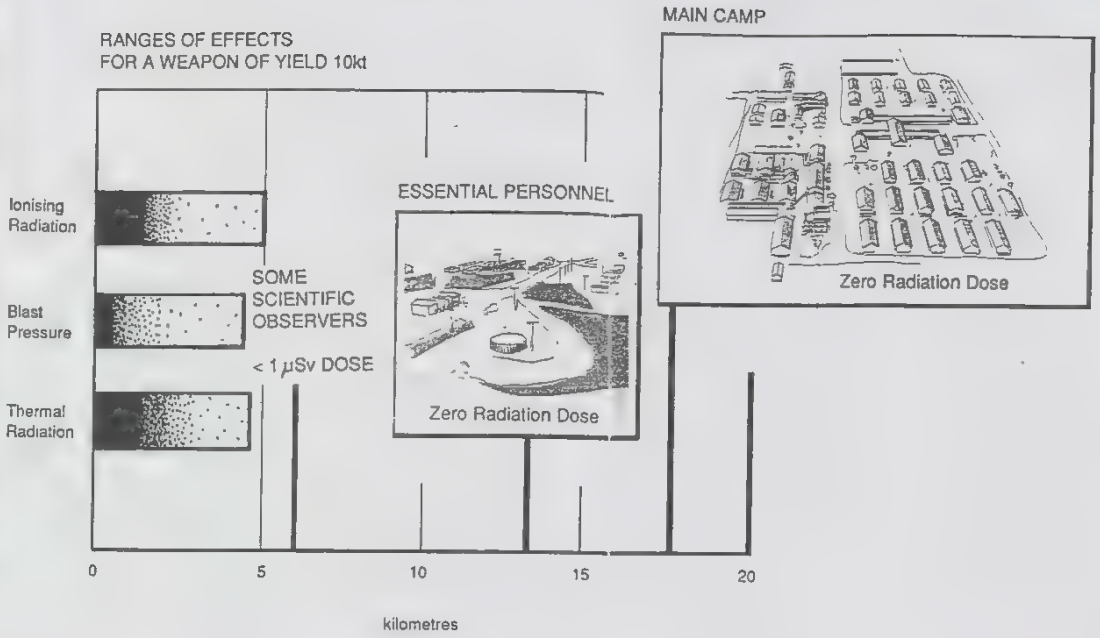
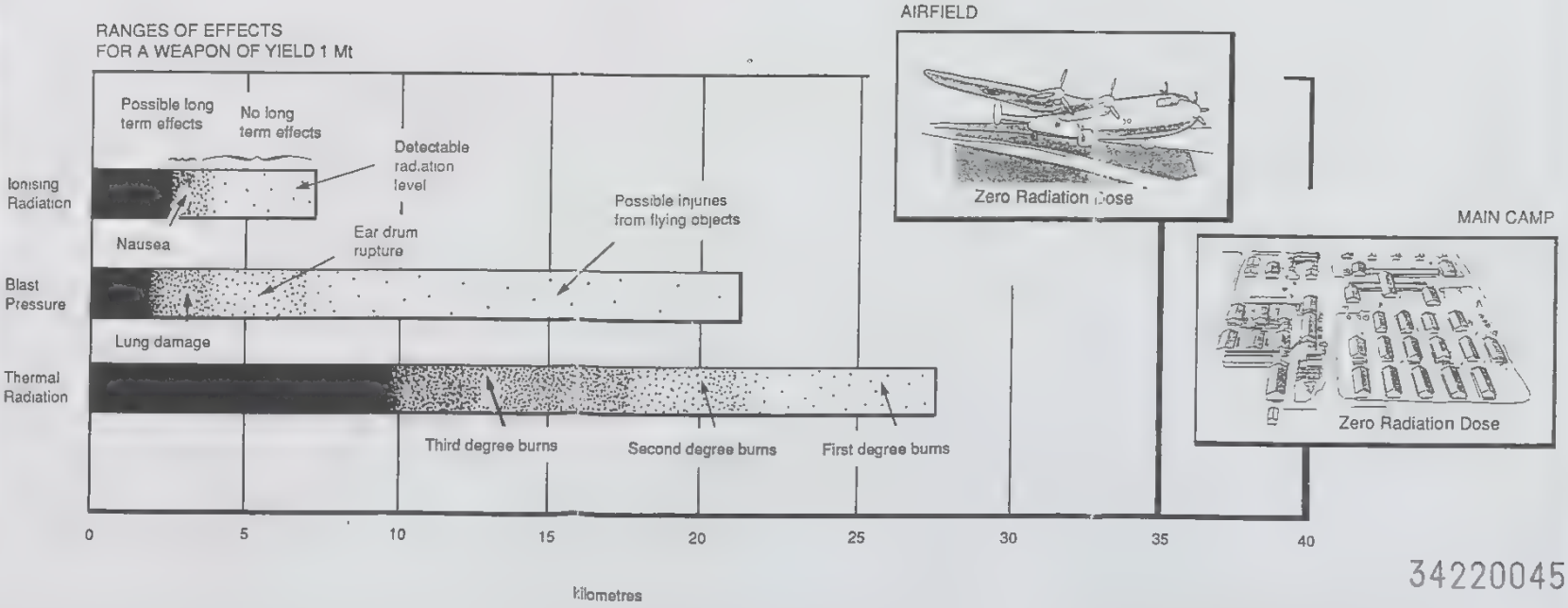
CHRISTMAS ISLAND

FIGURE 3

34220044





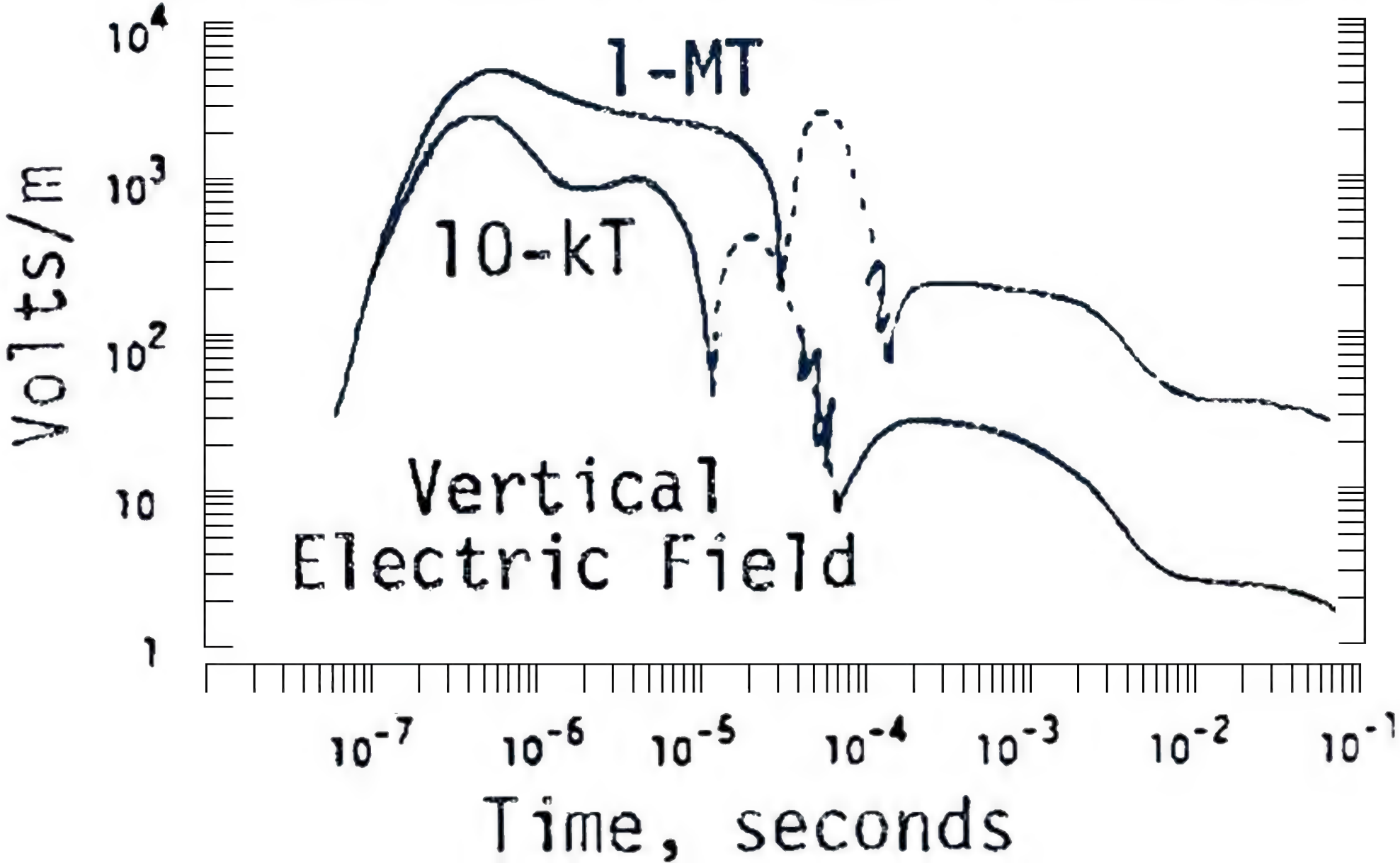
34220045

FIGURE 4

Effects of Nuclear Weapons on Unprotected Personnel

C. L. Longmire, "History and Physics of EMP," presentation at the Fourth NEM Symposium, Baltimore, Maryland, July 2, 1984.

10 km range from surface bursts (solid lines = negative fields; dashed lines = positive fields)



Science Applications, Inc.
Albuquerque, NM 87108

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Albuquerque, NM 87106

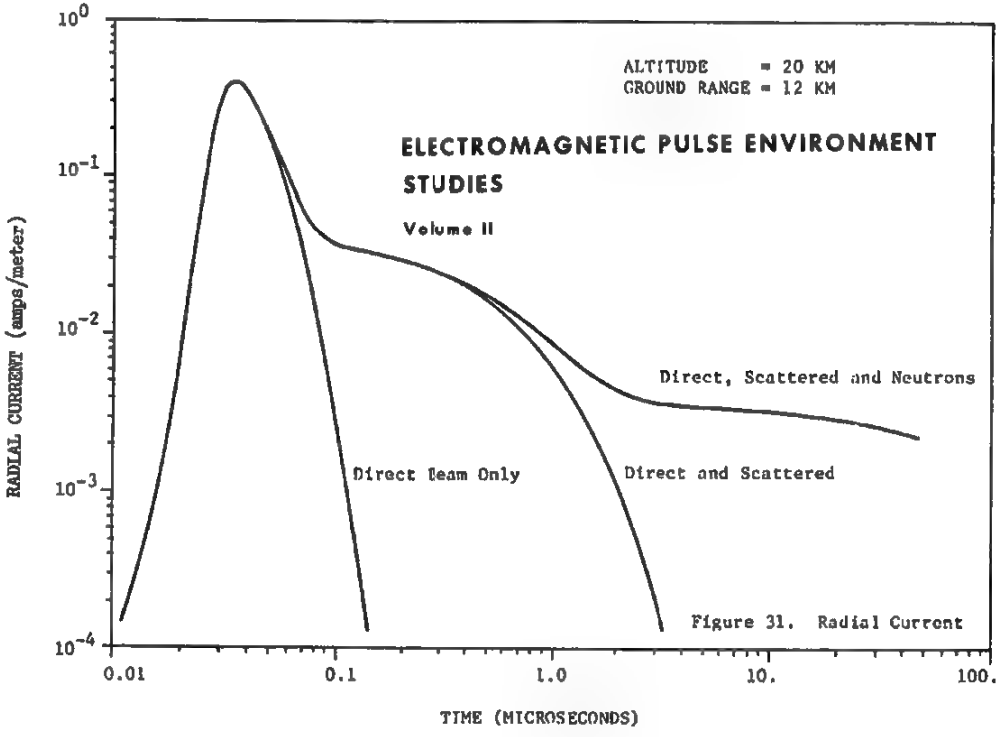

Figure 31. Radial Current

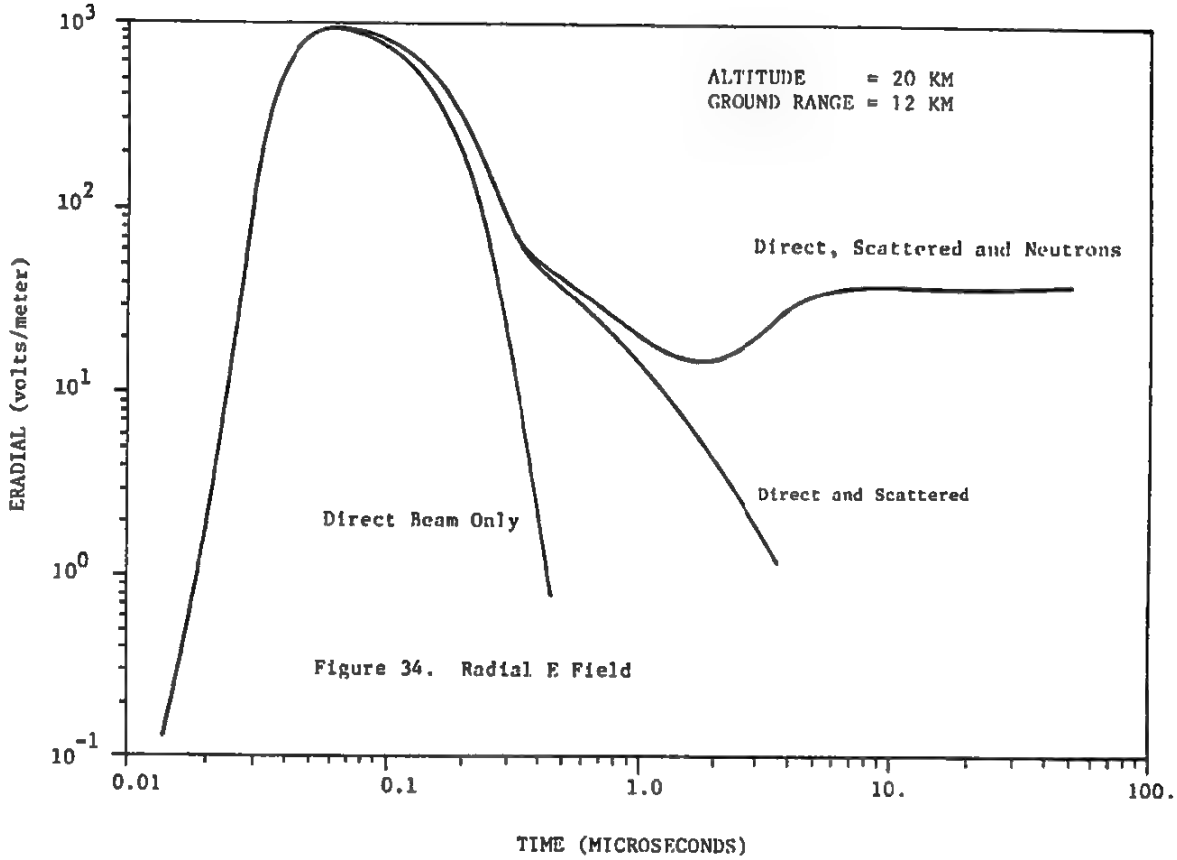

Figure 34. Radial E Field

3.53Mt, 15% fission Redwing-Zuni surface burst, 1956 at Bikini Atoll

[redacted]

[redacted] (ZUNI)

Project 6.5 - Analysis of Electromagnetic Pulse Produced by a Nuclear Explosion - Charles J. Ong

OBJECTIVE

The objective of Project 6.5 is to obtain waveforms of the electromagnetic radiation for all the detonations during Operation REDWING. This data is to be used in connection with a continuing study relating the wave form parameters to the height and yield of the detonation.

INSTRUMENTATION

Two identical stations are used to record data, one at Eniwetok and one at Kwajalein.

The instrumentation consists of a wide-band receiver with separate outputs connected to each of the three oscilloscopes. Mounted on each oscilloscope is a Polariod Land Camera for recording the transient display.

RESULTS

Station A: Eniwetok

The predicted field strength [redacted] was 16.0 volts per meter. The measured field strength [redacted] was 14.4 volts per meter. The general waveform for the 1.0 μ sec/cm sweep was poor but the waveforms recorded for the other two scopes were good.

Station B: Kwajalein

No record data due to the loss of timing with WWVH.

CONCLUSIONS

All data has been forwarded to Evans Signal Laboratory for final analysis.

[redacted]

Chapter 10
TEST of SERVICE EQUIPMENT and MATERIALS

10.3 WAVE FORM OF ELECTROMAGNETIC PULSE FROM NUCLEAR DETONATIONS

The objective was to obtain and analyze the wave form of the electromagnetic (EM) pulse resulting from nuclear detonations. In particular, broad-band measurements were made from 0 to 10 Mc at ranges up to 460 miles.

Previous measurements of the EM pulse were made during Operations Crossroads, Sandstone, Greenhouse, Buster-Jangle, Tumbler-Snapper, Ivy, Upshot-Knothole, Castle, Teapot, and Redwing. The equipment used for these measurements ranged from narrow-band tuned receivers to broad-band untuned receivers. The antennas used with these receivers varied from simple probes to specially designed discones. Equipment similar to that used by Operation Hardtack Project 6.4 had been used during Operation Castle. In general, the EM-pulse energy was found to be predominantly in the low frequencies (approximately 10 to 20 kc), with measurable components at frequencies as high as 300 Mc. The duration of the EM pulse was found to be approximately 50 μsec, with an initial rise time as short as 10 μsec.

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Two stations were used: Kusaie, 460 miles from Bikini and 420 miles from Eniwetok; and Wotho, 100 miles from Bikini and 240 miles from Eniwetok. . . .

Shot Yucca (see Figures 10.1 and 10.2). No data was recorded at Wotho for this shot because of technical photographic problems. Several camera shutters did not open. Trace intensity was, in general, too low for proper recording. Also, field strength at Kusaie indicated that deflection at Wotho would have been some five times the scope limits.

All scopes at Kusaie triggered, and the signal was recorded. The wave form was radically different from that expected. The initial pulse was positive, instead of the usual negative. The signal consisted mostly of high frequencies of the order of 4 Mc, instead of the primary lower-frequency component normally received (Figures 10.1 and 10.2). The fact that Shot Yucca was a very-high-altitude shot may have provided a more favorable propagation path for the higher frequencies that were recorded.

Shot Cactus (see Figures 10.3, 10.4 and 10.5). The signal from this shot was received and recorded at Wotho. A secondary positive spike appeared in the signal, even though a single-

347 stage nuclear device was used (Figure 10.4).

TABLE 10.1 WAVE FORM AND SHOT PARAMETERS

Shot	Yield	Number of Stages	Range	Peak Negative Field Strength	Plateau Negative Field Strength
	kt		miles	v/m	v/m
WOTHO DATA:					
Cactus	17	Single	240	1.7	0.92
Fir	1,360	Two	100	6.4	2.6
Butternut	82	Two	240	2.8	1.3
Koa	1,370	Two	240	1.2	—
Holly	5.75	Single	240	1.2	0.82
Nutmeg	22.5	Two	100	8.0	2.9
KUSAIE DATA:					
Yucca	2.0	Single	440	0.45	
Butternut	82	Two	460	0.33	
Koa	1,370	Two	460	0.28	
Holly	5.75	Single	460	0.18	
Nutmeg	22.5	Two	440	0.54	

354

Hardtack ITR 1660 summary extracts

AD369152

[redacted] (FLATHEAD)

Project 6.5 - Analysis of Electromagnetic Pulse Produced by Nuclear Explosion - C. J. Ong

Objective

The objective of Project 6.5 is to obtain waveforms of the electromagnetic radiation for all the detonations during Operation REDWING. This data is to be used in connection with a continuing study relating the waveform parameters to the height and yield of the detonation.

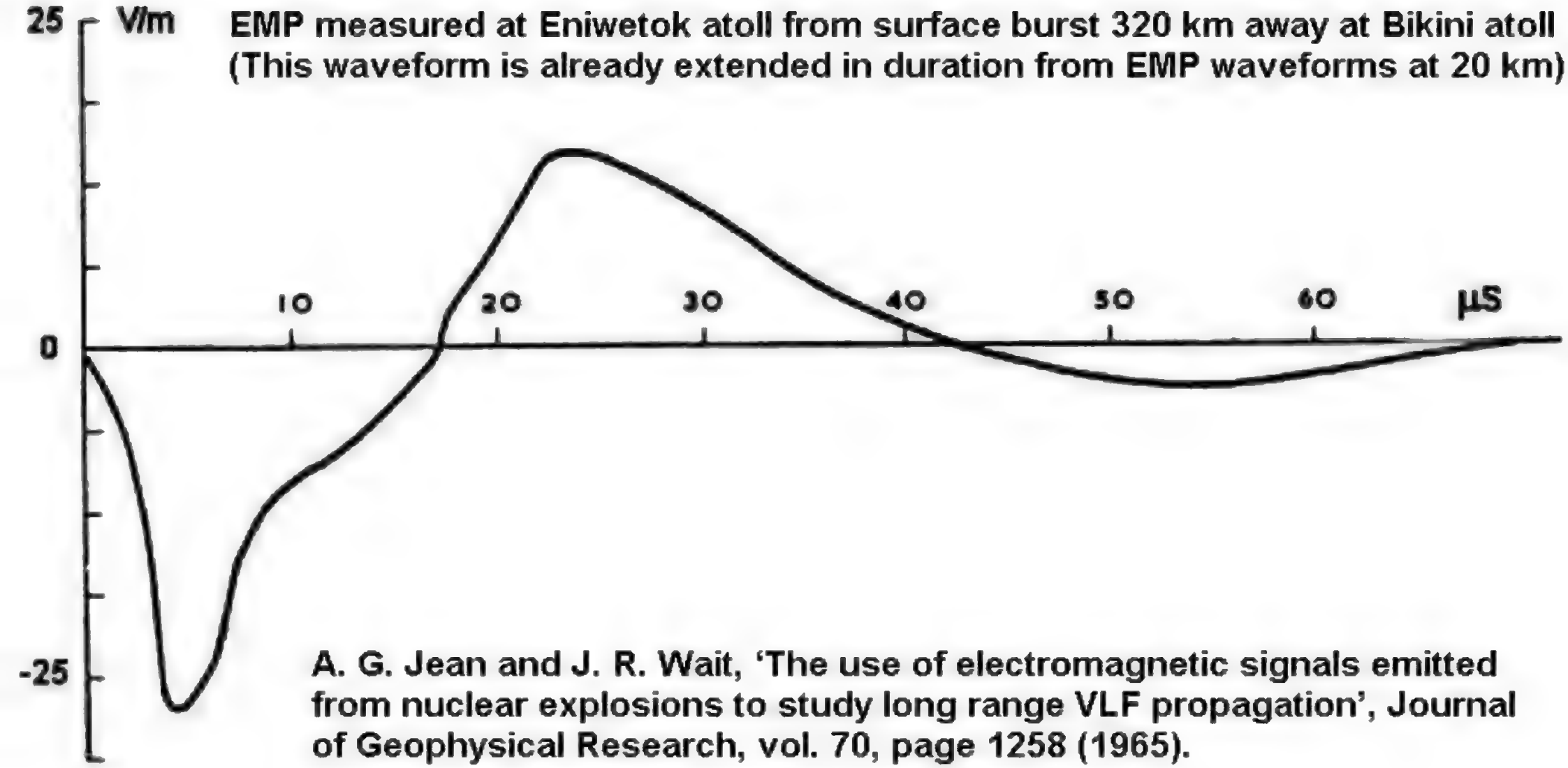
Instrumentation

Two identical stations are used to record data, one at Eniwetok and one at Kwajalein.

The instrumentation consists of a wide-band receiver with separate outputs connected to each of the three oscilloscopes. Mounted on each oscilloscope is a Polaroid Land Camera for recording the transient display.

The wide-band receiver consists of one primary and four secondary cathode follower amplifiers. An antenna, frequency insensitive in the range of interest is fed directly into the primary cathode follower. The primary cathode follower is then connected to four individual cathode followers by a 50-ohm coaxial cable. Only three secondary cathode followers are utilized, the fourth serving as a spare.

The number one and two cathode followers feed oscilloscopes with sweep speeds of approximately 30 micro-seconds per centimeter and 10 microseconds/centimeter respectively. The number three cathode follower is connected to the third oscilloscope through a 2 micro-second delay line. The third oscilloscope has a sweep speed of 1.0 micro-seconds/centimeter. All oscilloscopes were triggered simultaneously by the DC



A. G. Jean and J. R. Wait, 'The use of electromagnetic signals emitted from nuclear explosions to study long range VLF propagation', Journal of Geophysical Research, vol. 70, page 1258 (1965).

trigger device located in the primary cathode follower and connected directly to the receiving antenna. The 2 micro-second delay line was added to permit the leading edge of the waveform to be recorded.

In order to establish a definite time relationship between the reception of the signal and the triggering of a given device such as a counter or transmitter, a time marker pip, generated by the delay trigger from one of the oscilloscopes, is fed through the 2 micro-second delay line and superimposed on the initial portion of the received waveform.

Procedure

All oscilloscopes are calibrated against a known frequency standard for sweep linearity.

The cathode follower triggering system is set to trigger approximately 6 db. above the noise level. The vertical deflector of the oscilloscopes are set to receive the predicted field strength.

Results

Station A - Parry Island

Waveform traces were obtained on two oscilloscope photos and the third oscilloscope failed to function properly. The predicted field strength was 43.0 volts per meter and the measured field strength was 17.0 volts per meter. The waveform traces are of good quality.

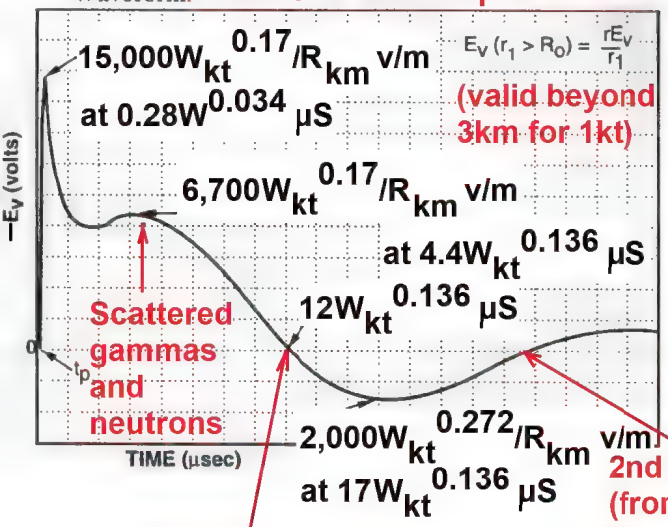
Station B - Kwajalein

Waveform traces were obtained on two oscilloscope photos and the third failed to trigger. The predicted field strength was 25.0 volts per meter and the measured field strength was 6.8 volts per meter.

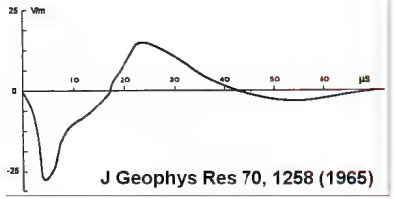
LANL RC

L 8

Figure 10.20. Generic Radiated Ground-Burst EMP Waveform. From J. A. Northrop 1996 EM-1



Eniwetok-Bikini 320 km



In a built-up city, steel framed and concrete buildings rapidly attenuate this EMP!

Left: at 320 km, the HF frequency peak of 0.3 μS has disappeared due to frequency dependent attenuation. The times to cross-over have also increased. At long distances, the times are extended by multipath distortion due the EMP being chanelled from bomb to target by multiple reflections between the conductive ocean surface and the ionosphere, which act as a waveguide in the same way that you can pipe microwaves through a waveguide consisting of a hollow metal tube from source to antenna.

'The first attempt at a theory of [surface burst] radioflash was by [T.S.] Popham, in 1954, who suggested that radio signals were due to currents carried by Compton electrons arising from gamma rays produced in the nuclear explosion... Both the period and amplitude of the radio signal would be expected to increase very slightly with yield.'

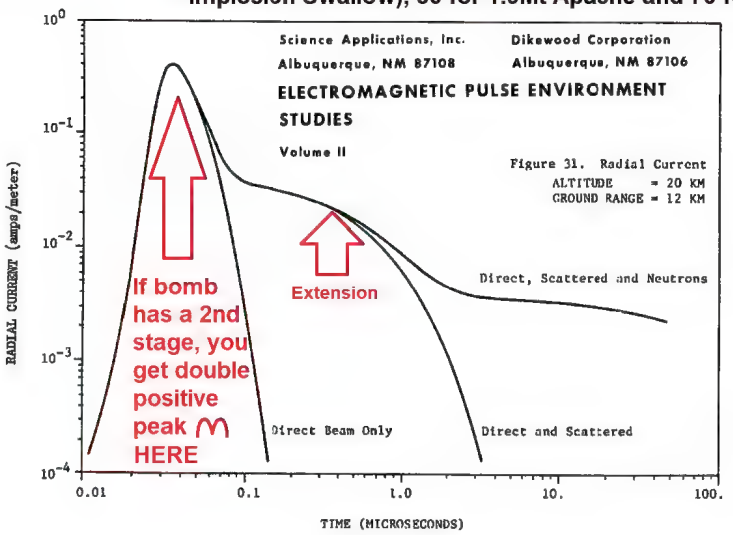
- J.B. Taylor, A Theory of Radioflash, U.K. Atomic Weapons Research Establishment, report AWRE-O33/59, October 1959, Confidential, pp. 3-18.

Fig 1b by Taylor gives the EMP electric field from a ~1 kiloton surface burst (presumably the Marcoo 1.5 kt shot in 1956 at Maralinga): the peak field measured at a distance of 300 km is ~28.1 v/m in the NEGATIVE direction at a time of 5 microseconds. Zero field is at 17.2 microseconds. Peak positive is at 23 microseconds with ~15.4 v/m and second zero is at 42.5 microseconds. Second negative is at 54 microseconds with about ~ 3.75 v/m.

HENCE AT A DISTANCE OF 300 KM, FREQUENCY-DEPENDENT ATTENUATION INCREASES THE TIME SCALE OF THE FIRST FULL CYCLE OF THE RADIATED EMP FROM A SURFACE BURST BY A FACTOR OF TWENTY. HENCE THE PEAK FREQUENCY IS LOWER BY A FACTOR OF TWENTY AT 300 KM THAN IT IS AT 20 KM. Hence for a 1 kt surface burst, the peak close-in frequency of 1 MHz falls to just 50 kHz at 300 km.

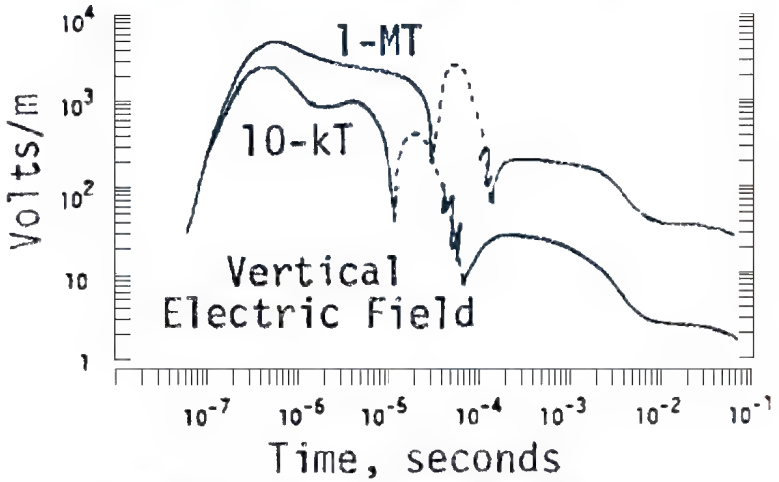
AFWL-TR-73-286, Vol II

Table 7.2 in Redwing series weapon test report WT-1344 states that 2nd crossover occurred at 29 μS for 1.5kt Kickapoo (linear implosion Swallow), 50 for 1.9Mt Apache and 70 for 4.5Mt Navajo



Logarithmic plot of surface burst EMP waveforms:

10 km range from surface bursts (solid lines = negative fields; dashed lines = positive fields)



C. L. Longmire, "History and Physics of EMP," presentation at the Fourth NEM Symposium, Baltimore, Maryland, July 2, 1984.

For a nuclear weapon, the radius of the ionized region, a, producing the electromagnetic pulse was estimated from the relation

$$W = 4.55 \times 10^{-5}\ a \exp\left\{25\left[1-\exp\left(-0.1254a\right)\right]\right\} \quad (1.2)$$

Where: W = yield Mt

a = effective radius, kilometers.

$$E_{max} = \frac{3000\ a}{R}\left[1 - \frac{(a)^2}{R} + \frac{(a)^4}{R}\right]^{\frac{1}{2}} \quad (1.3)$$

Where:

E_{max} = peak electric field, volts/meter

a = effective radius, feet

R = distance, feet

Low-frequency magnetic fields could not be predicted reliably. The maximum value for the high-frequency horizontal component was estimated from the equation:

$$H_{\phi} = \left[100\ \frac{W}{R^2}\ \exp.\ (-2.5R)\right]^{0.43} \quad (1.4)$$

Where:

H_{ϕ} = horizontal component, oersteds

R = distance, kilometers

W = yield, Mt

ABOVE: surface burst EMP data from pages 16-17 of POR-2239 / weapon test report WT-2239, by P. J. Sykes, Jr., "Operation Sunbeam, Project Small Boy, Project Officers Report - Project 7.1.4, Transient Radiation Effects Measurements on Guidance Systems Circuits", DTIC AD-A995 378

M. H. OLESON, "OPERATION IVY, PROJECT 7.1, REPORT TO THE SCIENTIFIC DIRECTOR, ELECTROMAGNETIC EFFECTS FROM NUCLEAR EXPLOSIONS," nuclear weapons test report WT-644, AD-A995 500

FIGURE 15. EMP WAVEFORM FROM 500 KILOTON KING ENIWETOK TEST IN 1952, RECORDED AT MAUI.

Page 9: "During Ranger (Nevada, January-February, 1951) large excursions were noted on a Brush recorder attached to a long wire and crystal diode. Hastily-planned measurements, using oscilloscopes, during Greenhouse (Eniwetok, early Summer, 1951) demonstrated pulses with sharp rise times coincident with the detonation of the nuclear devices. In the Fall of 1951 (Nevada,Buster-Jangle) electromagnetic effects which could be fairly well correlated with the atomic explosions were reported by stations at varying distances from the detonation points."

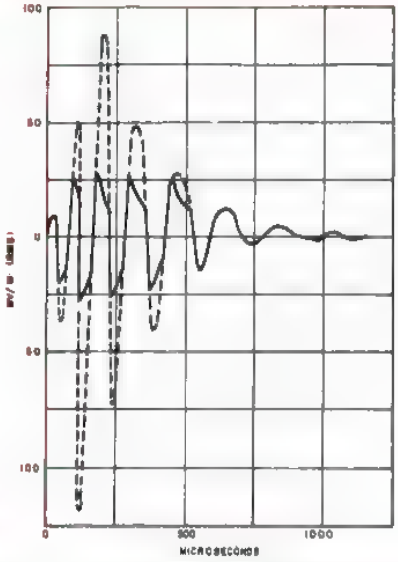
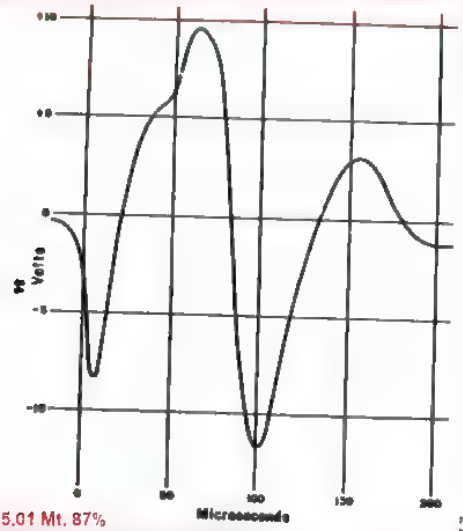


Figure 17 Shot King - National Bureau of Standards broad band wave form recorded at Stanford University. Dotted sections show probable shape.



5.01 Mt, 87% fission, 178 km

Figure 2.2 Shot Tewa

3.2.1 Shot Tewa. During Shot Tewa, the sixteenth of the seventeen Redwing test shots, the aircraft was 90 naut mi (178 km) south of the detonation, at the 10,000-foot altitude which was usual for the flights. The signals received on the two fiducial antennas were both shown in the dual-beam oscilloscope, Type 333. The amplified signal from the smaller fiducial antenna, mounted inside the aircraft on the window rack, was displayed on Channel A, while Channel B displayed the signal from the larger antenna, mounted outside the aircraft skin.

Operation Redwing, Nuclear Weapon test report WT-1352

AJ Waters, OPERATION REDWING-PROJECT 6.4 AIRBORNE ANTENNAS

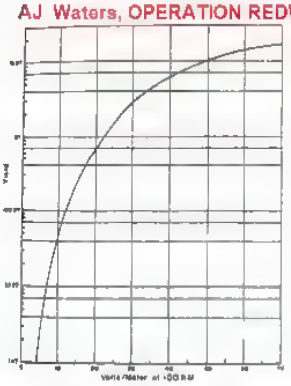


Figure 4.4 Empirical relation between detonation yield and the field strength of the electromagnetic pulse, referred to a range of 100 km (54 naut mi).

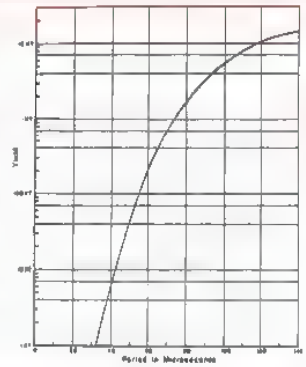


Figure 4.5 Empirical curve relating detonation yield and the period of the electromagnetic pulse.

A Glenn Jean, "National Bureau of Standards, Preliminary Report on Castle, Project No. A/419/NBS", DTIC report AD0338553 (partially declassified in 2013):

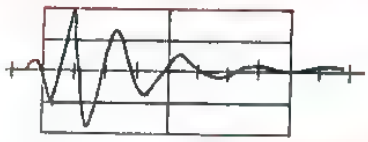


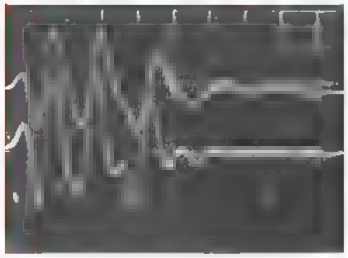
Fig. 11

RG18/U
Maui, 4200 km path
Sweep rate 50 usec/cm
Sensitivity 0.08 v/m/cm

11 megatons Castle-Romeo surface burst

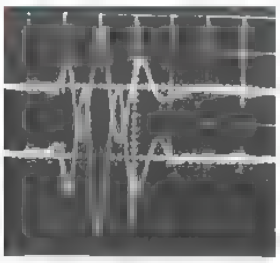
EMP measured from the 5.01 megaton, 87% fission Redwing-Tewa surface burst, Bikini Atoll, 1956 (source: ADA995297)

Figure 3.37 Experimental signal tape, Shot Bighorn



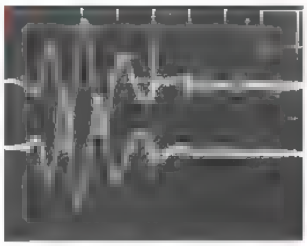
BIGHORN SS LOYALTY
Upper-loop, wer-whip
Sweep speed, usec/cm

Figure 3.33 Experimental signal, tape Shot Rinconada



RINCONADA USS LOYALTY
Upper-loop wer-whip
Sweep speed usec/cm

Figure 3.32 Experimental signal, tape, Shot Harlem



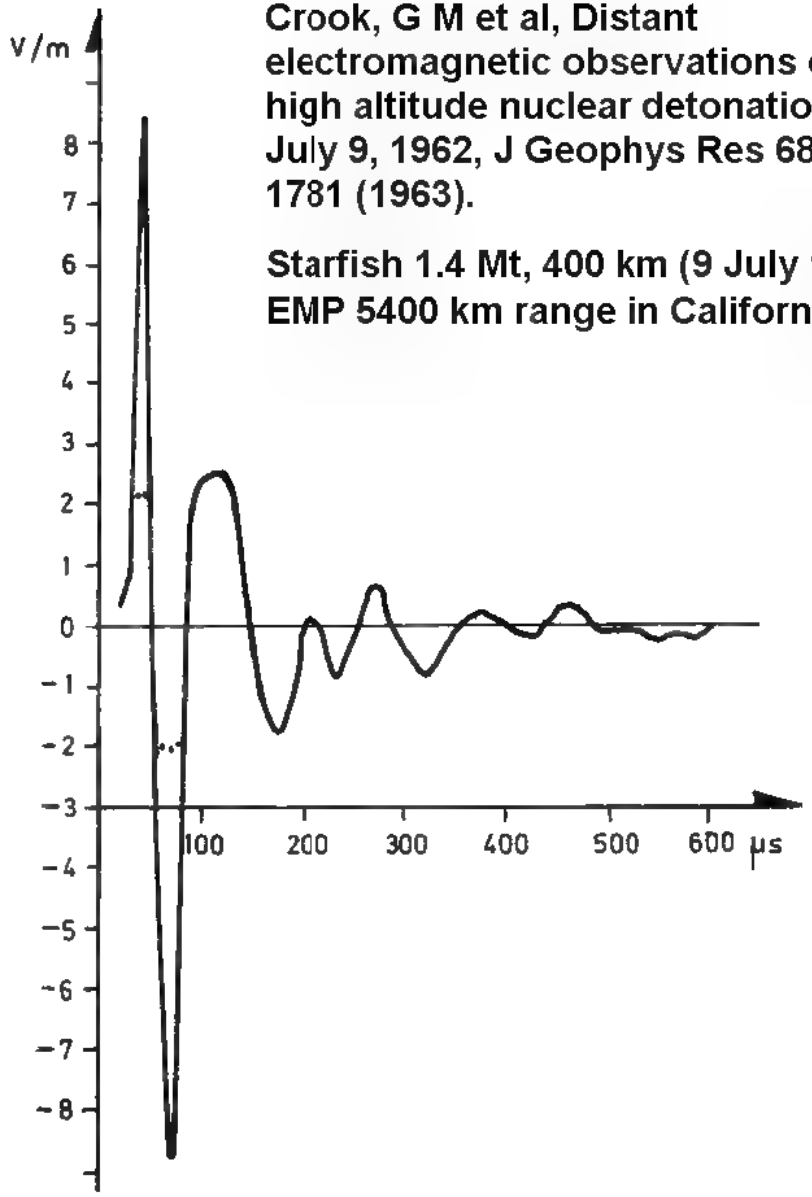
HARLEM USS LOYALTY
Upper-loop wer-whip
Sweep speed, 0.1 usec/cm

A. P. BRIDGES, ET AL., "OPERATION DOMINIC AND FISH BOWL SERIES, PROJECT OFFICERS REPORT - PROJECT 7.1, UNDERWATER EMP", POR-2033, weapon test report WT-2033, AD-A995 288, page 9:

"The electromagnetic (EM) signal from a nuclear detonation has a waveform that has definite characteristics and is repeatable. It has been proposed to use this phenomena as the basis of a terminal surveillance system for use aboard the Polaris. "

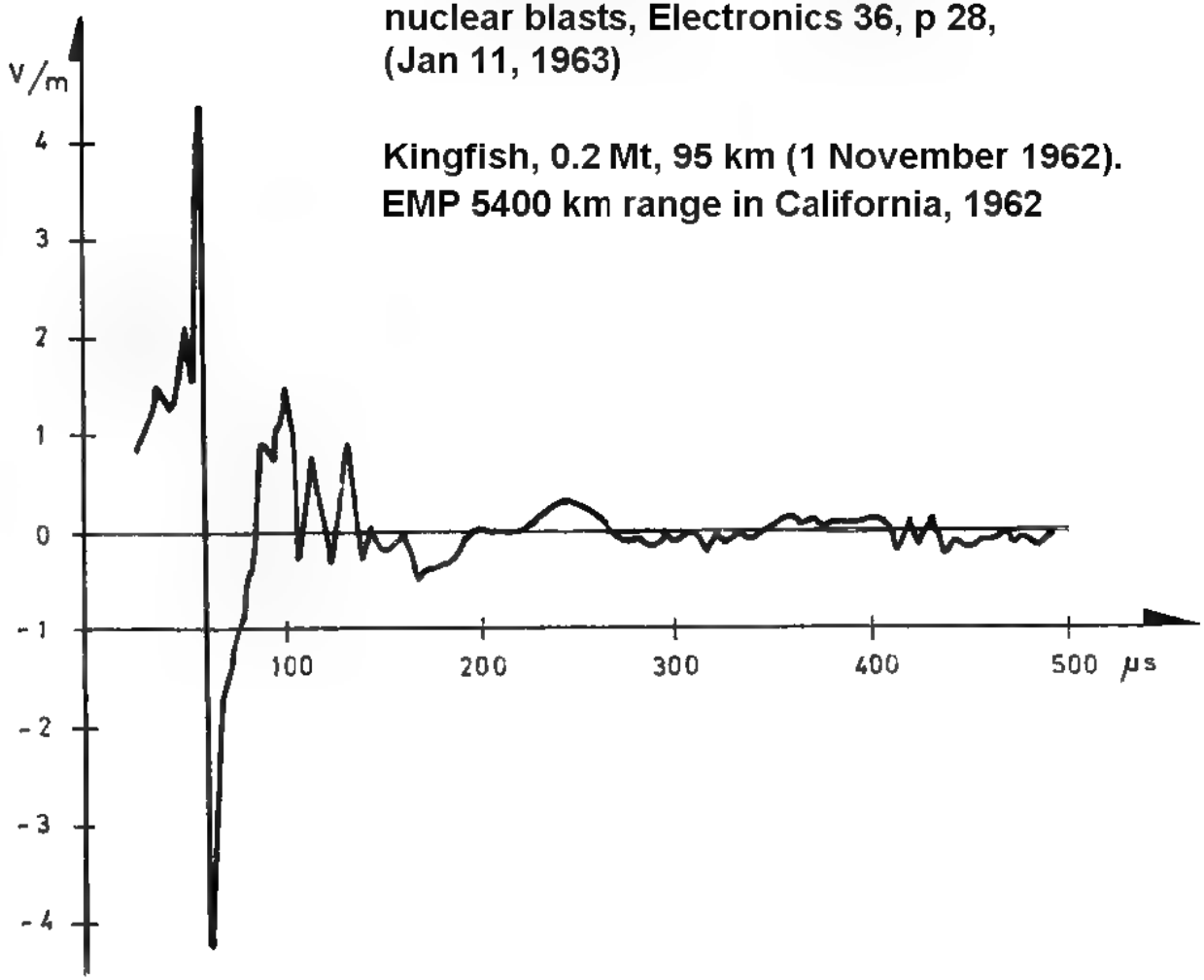
Crook, G M et al, Distant electromagnetic observations of the high altitude nuclear detonation of July 9, 1962, J Geophys Res 68, p 1781 (1963).

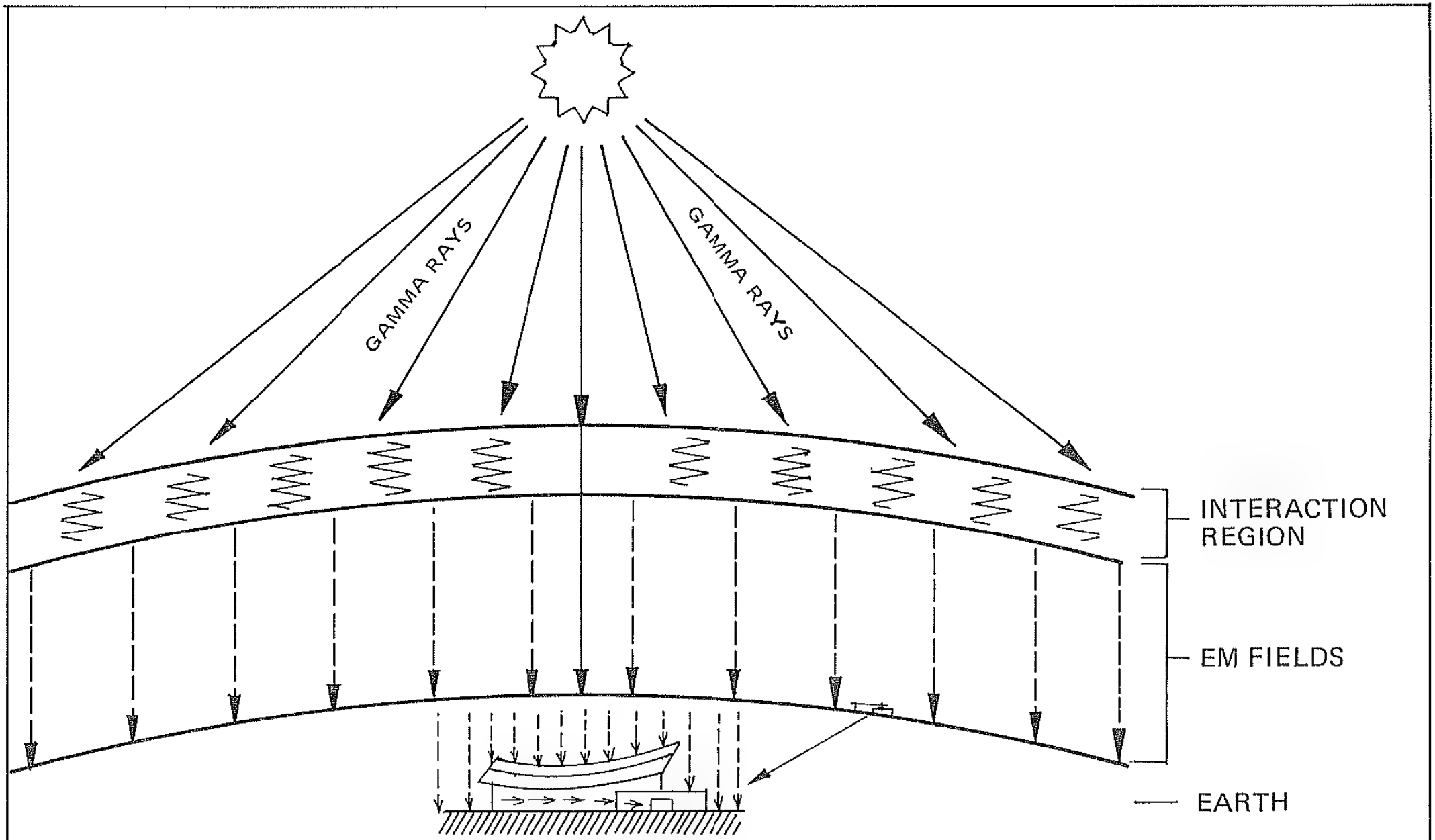
Starfish 1.4 Mt, 400 km (9 July 1962). EMP 5400 km range in California, 1962



How radio can plot high altitude nuclear blasts, Electronics 36, p 28, (Jan 11, 1963)

Kingfish, 0.2 Mt, 95 km (1 November 1962). EMP 5400 km range in California, 1962



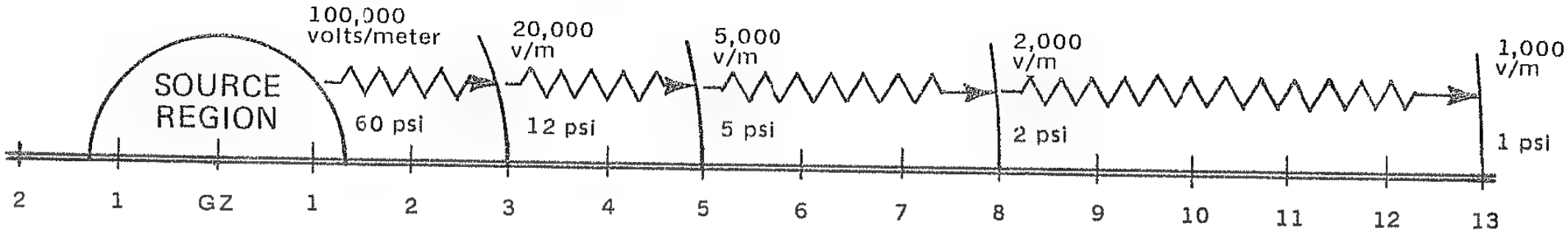


EMP ENERGY FROM HIGH ALTITUDE BURST.

Survive, November-December 1969.

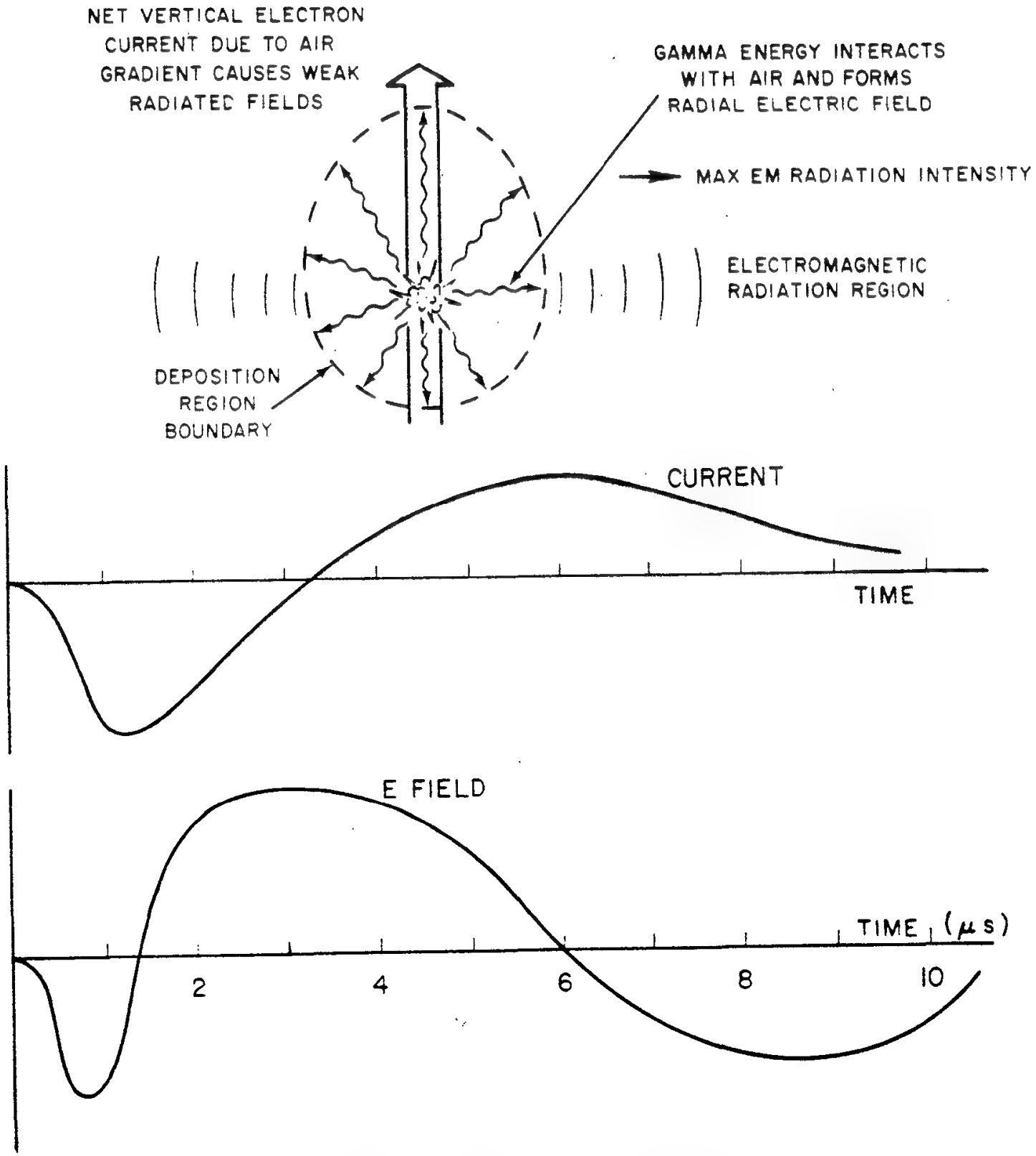
EMP FROM A 5–MT SURFACE BURST

SOURCE	INTENSITY (volts per meter)
EMP	UP TO 100,000
RADAR	200
RADIO COMMUNICATION	10



DISTANCE FROM GZ, MILES

Source: Defense Nuclear Agency



Comparison of General Waveforms for the Dipole Moment, the Current, and the E-Field for and Air Burst

OPERATION CASTLE

PROJECT 7.1

ELECTROMAGNETIC RADIATION CALIBRATION

PACIFIC PROVING GROUNDS

March - May 1954

M. H. Olseon

Headquarters Field Command
Armed Forces Special Weapons Project
Sandia Base, Albuquerque, New Mexico

June 13, 1958

NOTICE

This is an extract of WT-930, which remains classified SECRET/RESTRICTED DATA as of this date.

Extract version prepared for:

Director

Defense Nuclear Agency

Washington, D. C. 20305

31 August 1984

Approved for public release; distribution unlimited.

OBJECTIVES

In order to gain maximum information on nuclear detonations as determined from the electromagnetic pulse received at distances, there are two fundamental problems; first, the discrimination of nuclear-weapon pulses from natural atmospherics and second, the determination of the maximum information on the source itself and external conditions at detonation time, from the characteristics of the selected pulse. The 7.1 Castle project offered an opportunity to monitor detonations of nuclear devices of known composition and characteristics.

BACKGROUND

AFOAT-1 has supported experimental measurements of the pulse emitted at the time of a nuclear detonation during each series of atomic tests beginning with Buster-Jangle (Autumn, 1951). As a result of these experiments (References 1,2,3), the following can be stated with some assurance:

1. There is an electromagnetic pulse less than 100 μsec long emitted at the time of a nuclear detonation.
2. At a distance of 20 km from the generating source, the field strength may be a few hundred volts per meter.
3. There is a general relationship between kiloton yield and the vertical component of the electromagnetic field.
4. The emitted frequency spectrum extends from about 2 kc or below up to a few megacycles, but the main components are in the region of about 6 to 50 kc.
5. There is an approximate inverse relationship between yield and predominant frequency.
6. Pulses received close-in (i.e. approximately 20 km) exhibit very short rise times (less than a microsecond) in a negative direction (i.e. the electric field vector is downward).
7. The pulse is predominantly vertically polarized.
8. Close-in reception indicates that certain nuclear-weapon characteristics can be determined from pulse fine structure.
9. Even low-yield nuclear detonations can produce a pulse receivable at distances in excess of 1,000 km.
10. The ground wave is generally not detectable beyond about 1,500 km from the source because the ionospheric sky wave reflections predominate.
11. A fix of the source of the pulse can be obtained with direction-finding equipment; observed azimuthal errors to date using equipment tuned to 10 kc have been between 0 and 9 degrees; most errors have been less than 3 degrees.
12. At distances, the pulse is extended to approximately ten times its close-in length. This is the result of multiple arrivals by various paths, each characterized by one or more ionospheric reflection.
13. Close-in fine structure disappears during sky wave propagation to distances.

TABLE 1 SUMMARY OF CASTLE RESULTS

Station/Agency Distance (km) and calculated azimuths to Bikini (B) and Eniwetok (E)	Time as received at the station (Z), corrected for nuclear detonation pulse and WWV transmission times; Remarks; Recorded azimuths to detonation points; Field Strength data (v/m); a. Broad-band, center-to-peak (W whip, L loop); b. Narrow-band.	
	Shot 1 - 28 February 1954 - 1845:00.011Z Detonated at Bikini	Shot 2 - 26 March 1954 - 1830:00.378Z Detonated at Bikini
Eniwetok/NBS B 20 and 320 E 23	Radioactive debris fogged waveform equipment on Enyu Island, Bikini Atoll (20 km from detonation point).	1830:00.378 Waveform equipment was moved to Runit Island, Eniwetok for the balance of the series. a. ~ 21.0 (W)
Guam/NBS B 2,270 E 1,920	1845:00.011 a. 0.34 (W)	1830:00.378 a. 1.54 (W) b. 0.036 (8 kc) 0.042 (12.5 kc) 0.023 (20 kc)
Maui/NBS B 4,200 E 4,420	1845:00.010 a. 1.97 (W) b. 0.23 (8 kc) 0.26 (12.5 kc) 0.026 (20 kc)	No time record. a. 1.79 (W)
Shemya/DRL B 4,680; 209° E 4,750; 214°	Alert notification not received in time.	1830:00.376 a. 0.054 (L) 210° ±3°
Pt. Barrow/NBS B 7,280 E 7,360	Poor timing record. a. 0.52 (W)	1830:00.378 a. 0.61 (W) b. 0.010 (8 kc) 0.011 (12.5 kc) 0.00097 (20 kc)
Stanford Univ/NBS B 7,740 E 8,000	Not in operation.	1830:00.377 a. 0.42 (W) b. 0.020 (8 kc) 0.018 (12.5 kc) 0.0018 (20 kc)
Larson AFB/AF B 8,030; 267° E 8,200; 269°	Off scale. 270° ±3°	1830:00.5 * 271° ±3°
Boulder/NBS B 9,200 E 9,460	1845:00.012 a. 0.38 (W) b. 0.014 (8 kc) 0.16 (12.5 kc) 0.0015 (20 kc)	1830:00.379 a. 0.34 (W) b. 0.016 (12.5 kc) 0.0015 (20 kc)
Thule/DRL B 9,630; 307° ±1° E 9,700; 310° ±1°	Alert notification not received in time.	1830:00.378 a. ~ 0.02 (W) 310° ±3° 0.025 (L)
Duluth/AF B 10,080; 287° E 10,280; 289°	Not in operation.	Not in operation.
Austin/DRL B 10,100; 282° ±1° E 10,350; 284° ±1°	1845:00.011 a. 0.68 (W) 287° ±3° 0.083 (L)	1830:00.378 a. 1.10 (W) 0.13 (L)
Ft Belvoir/NBS B 11,530 E 11,750	1845:00.011 b. 0.006 (8 kc) 0.0044 (12.5 kc)	1830:00.378 a. 0.080 (W) b. 0.0054 (8 kc) 0.0052 (12.5 kc) 0.00078 (20 kc)
Andrews/AWS B 11,550; 296° E 11,770	Not in operation.	1830:00.32 * 300° ±3°
Dow AFB/AF B 11,750; 301° E 11,920	Equipment trouble.	1830:00.35 * 295° ±3°
W Palm Beach/AWS B 11,850; 291° E 12,070	1845:00.00 * 299° ±3°	1830:00.37 * 294° ±3°
Kirknewton/DRL B 12,510; 12° E 12,530; 17°	Alert notification not received in time.	Poor time correlation. 19° ±3° a. 0.049 (W)
Kindley AFB/AWS B 12,860; 302° E 13,100	1844:59.58 * 308° ±3°	Not in operation.

*Within limit of resolution.

oscope and photographed.

Local Timing. Annex A of Reference 3 has a detailed account of the National Bureau of Standards (NBS) local timing unit. A typical time record from a close-in station is shown in Figure 1 and one from a

TABLE 1 SUMMARY OF CASTLE RESULTS (Cont)

Station/Agency Distance (km) and calculated azimuths to Bikini (B) and Eniwetok (E)	Time as received at the station (Z), corrected for nuclear detonation pulse and WWV transmission times; Remarks; Recorded azimuths to detonation points; Field Strength data (v/m); a. Broad-band, center-to-peak (W whip, L loop); b. Narrow-band.	
	Shot 3 - 6 April 1954 - 1820:00.411Z Detonated at Bikini	Shot 4 - 25 April 1954 - 1810:00.691Z Detonated at Bikini
Eniwetok/NBS B 20 and 320 E 23	1820:00.411 a. ~15.0 (W)	1810:00.691 a. ~40.0 (W)
Guam/NBS B 2,270 E 1,920	1820:00.412 a. 0.61 (W) b. 0.0034 (8 kc) 0.0065 (12.5 kc) 0.0080 (20 kc)	1810:00.692 a. 1.06 (W) b. 0.023 (8 kc) 0.043 (12.5 kc) 0.020 (20 kc)
Maui/NBS B 4,200 E 4,420	1820:00.412 a. 0.27 (W) b. 0.010 (8 kc) 0.013 (12.5 kc) 0.0013 (20 kc)	No time record. a. 1.49 (W)
Shemya/DRL B 4,680; 209° E 4,750; 214°	Alert notification not received in time.	1810:00.689 a. 0.039 (W) 214° ±3° 0.33 (L)
Pt. Barrow/NBS B 7,280 E 7,360	Poor time record. a. 0.046 (W) b. 0.0026 (8 kc) 0.0096 (12.5 kc) 0.0031 (20 kc)	No time record. a. 0.29 (W)
Stanford Univ/NBS B 7,740 E 8,000	1820:00.412 a. 0.048 (W) b. 0.0023 (8 kc) 0.0033 (12.5 kc) 0.0020 (20 kc)	1810:00.691 a. 0.33 (W) b. 0.0055 (8 kc) 0.0087 (12.5 kc) 0.0012 (20 kc)
Larson AFB/AF B 8,030; 267° E 8,200; 269°	Record not available.	Doubtful record.
Boulder/NBS B 9,200 E 9,460	1820:00.412 a. 0.055 (W) b. 0.0011 (8 kc) 0.0028 (12.5 kc) 0.00031 (20 kc)	1810:00.690 a. 0.33 (W) b. 0.0080 (8 kc) 0.018 (12.5 kc) 0.0011 (20 kc)
Thule/DRL B 9,630; 307° ±1° E 9,700; 310° ±1°	1820:00.411 a. 0.0035 (W) 314° ±3° 0.0012 (L)	1810:00.691 a. 0.046 (W) 307° ±3° 0.025 (L)
Duluth/AF B 10,080; 287° E 10,280; 289°	Not in operation.	Record not available.
Austin/DRL B 10,100; 282° ±1° E 10,350; 284° ±1°	1820:00.411 a. 0.027 (W) 285° ±3° 0.016 (L)	1810:00.691 a. 0.27 (W) 288° ±3° 0.12 (L)
Ft Belvoir/NBS B 11,530 E 11,750	1820:00.412 a. 0.016 (W) b. 0.00075 (8 kc) 0.001 (12.5 kc) 0.00022 (20 kc)	1810:00.690 a. 0.090 (W) b. 0.0021 (8 kc) 0.0055 (12.5 kc) 0.00062 (20 kc)
Andrews/AWS B 11,550; 296° E 11,770	Results negative.	1810:00.69 * 294° ±3°
Dow AFB/AF B 11,750; 301° E 11,920	Results negative.	Heavy sferics activity.
W Palm Beach/AWS B 11,850; 291° E 12,070	Started too late.	Not in operation.
Kirknewton/DRL B 12,510; 12° E 12,530; 17°	1820:00.411 a. 0.013 (W) 29° ±3° 0.003 (L)	1810:00.692 a. 0.0096 (W) 22° ±3° 0.0059 (L)
Kindley AFB/AWS B 12,860; 302° E 13,100	Not in operation.	Not in operation.

*Within limit of resolution.

oscope and photographed.

Local Timing. Annex A of Reference 3 has a detailed account of the National Bureau of Standards (NBS) local timing unit. A typical time record from a close-in station is shown in Figure 1 and one from a

TABLE 1 SUMMARY OF CASTLE RESULTS (Cont)

Station/Agency Distance (km) and calculated azimuths to Bikini (B) and Eniwetok (E)	Time as received at the station (Z), corrected for nuclear detonation pulse and WWV transmission times; Remarks; Recorded azimuths to detonation points; Field Strength data (v/m); a. Broad-band, center-to-peak (W whip, L loop); b. Narrow-band.	
	Shot 5 - 4 May 1954 - 1810:00.156Z Detonated at Bikini	Shot 6 - 13 May 1954 - 1820:00.404Z Detonated at Eniwetok
Eniwetok/NBS B 20 and 320 E 23	1810:00.156 a. ~34.0 (W)	1820:00.404 a.~775.0 (W)
Guam/NBS B 2,270 E 1,920	1810:00.154 a. 1.45 (W) b. 0.090 (8 kc) 0.047 (12.5 kc) 0.029 (20 kc)	1820:00.404 a. ~1.46 (W) b. 0.035 (8 kc) 0.028 (12.5 kc) 0.041 (20 kc)
Maui/NBS B 4,200 E 4,420	1810:00.156 a. 1.81 (W) b. 0.12 (8 kc) 0.056 (12.5 kc) 0.011 (20 kc)	1820:00.404 a. 1.44 (W)
Shemya/DRL B 4,680; 209° E 4,750; 214°	1810:00.155 a. 0.073 (W) 215° ±3° 0.42 (L)	1820:00.401 a. 0.037 (W) 210° ±3° 0.38 (L)
Ft Barrow/NBS B 7,280 E 7,360	1810:00.158 a. 0.35 (W) b. 0.013 (8 kc) 0.014 (12.5 kc) 0.0011 (20 kc)	No time record. b. 0.013 (8 kc) 0.014 (12.5 kc) 0.0011 (20 kc)
Stanford Univ/NBS B 7,740 E 8,000	No record	1820:00.405 a. 0.51 (W) b. 0.012 (8 kc) 0.019 (12.5 kc) 0.00097 (20 kc)
Larson AFB/AF B 8,030; 267° E 8,200; 269°	Poor signal	1820:00.3 * 272° ±3°
Boulder/NBS B 9,200 E 9,460	1810:00.158 b. 0.013 (8 kc) 0.014 (12.5 kc) 0.00057 (20 kc)	1820:00.405 a. 0.30 (W) b. 0.0068 (8 kc) 0.017 (12.5 kc) 0.0017 (20 kc)
Thule/DRL B 9,630; 307° ±1° E 9,700; 310° ±1°	1810:00.157 a. 0.041 (W) 308° ±3° 0.032 (L)	1820:00.404 a. 0.071 (W) 310° ±3° 0.028 (L)
Duluth/AF B 10,080; 287° E 10,280; 289°	1810:00.17 * 288° ±3°	1820:00.3 * 288° ±3°
Austin/DRL B 10,100; 282° ±1° E 10,350; 284° ±1°	1810:00.158 a. 0.259 (W) 286° ±3° 0.14 (L)	1820:00.405 a. 0.24 (W) 291° ±3° 0.13 (L)
Ft Belvoir/NBS B 11,530 E 11,750	1810:00.158 a. 0.070 (W) b. 0.0037 (8 kc) 0.0040 (12.5 kc) 0.00031 (20 kc)	1820:00.405 a. 0.078 (W) b. 0.0020 (8 kc) 0.0056 (12.5 kc) 0.00084 (20 kc)
Andrews/AWS B 11,550; 296° E 11,770	1810:00.17 * 298° ±3°	Not in operation.
Dow AFB/AF B 11,750; 301° E 11,920	Record not available.	1820:00.2 *
W Palm Beach/AWS B 11,850; 291° E 12,070	1810:00.14 * 292° ±3°	Not in operation.
Kirknewton/DRL B 12,510; 12° E 12,530; 17°	1810:00.158 a. 0.0086 (W) 26° ±3° 0.0063 (L)	1820:00.404 a. 0.012 (W) 21° ±3° 0.0070 (L)
Kindley AFB/AWS B 12,860; 302° E 13,100	1810:00.18 * 306° ±3°	Not in operation.

*Within limit of resolution.

oscope and photographed.

Local Timing. Annex A of Reference 3 has a detailed account of the National Bureau of Standards (NBS) local timing unit. A typical time record from a close-in station is shown in Figure 1 and one from a

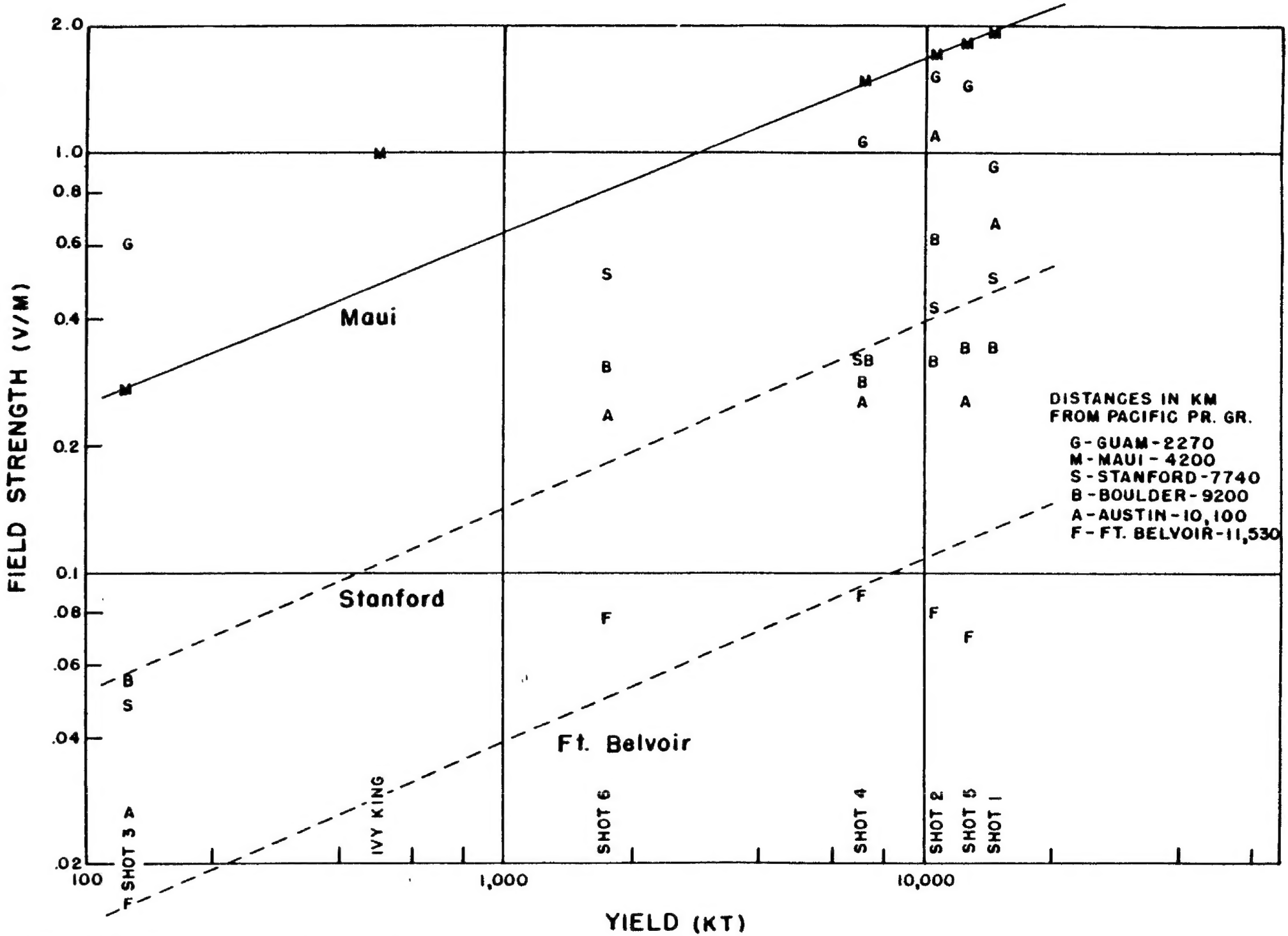


Figure 5 Plot of selected Castle data showing the relationship between peak field strength and yield on an east-west path. Probable curves, drawn by inspection, are shown for Maui, Stanford University and Ft. Belvoir.

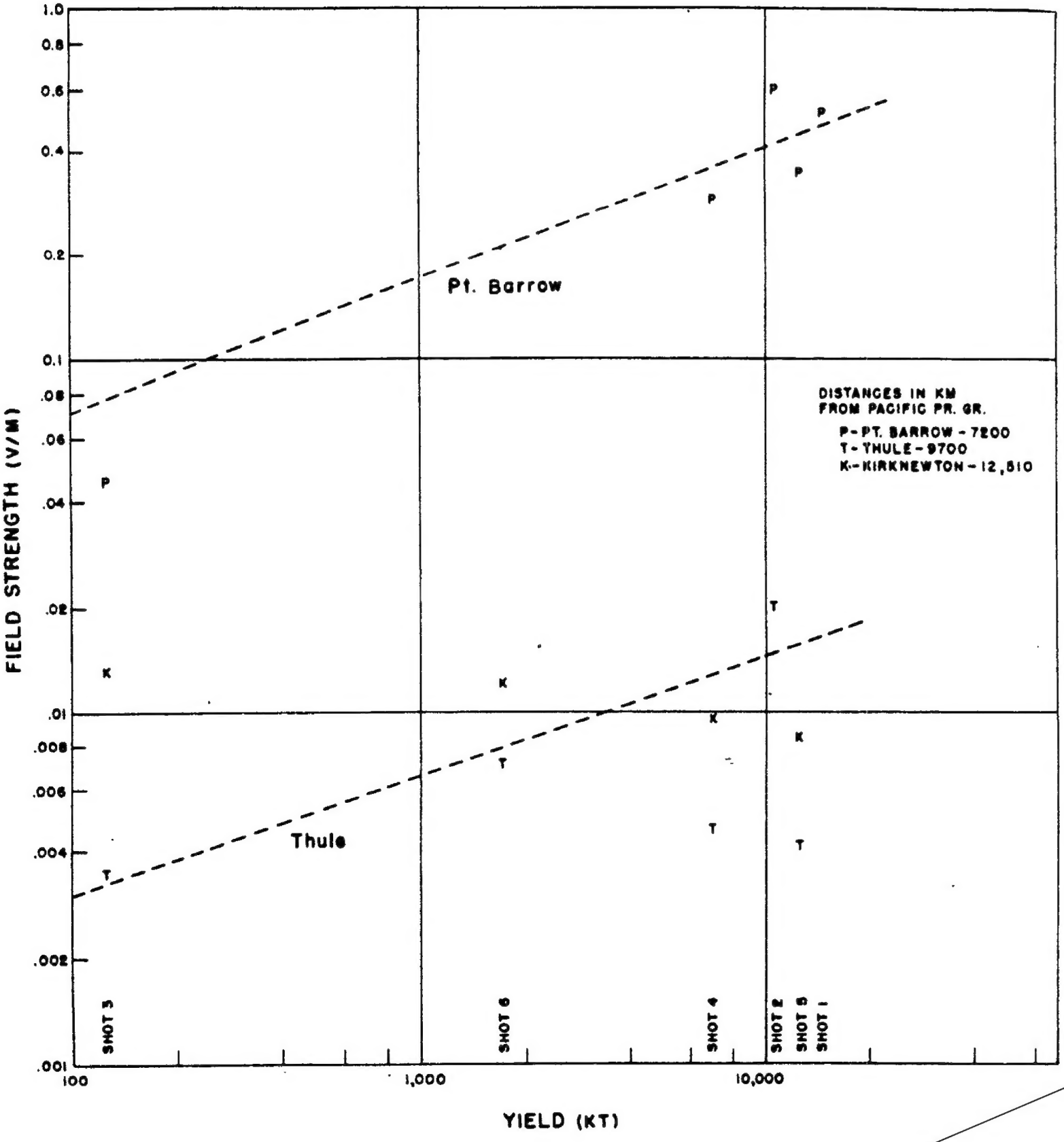
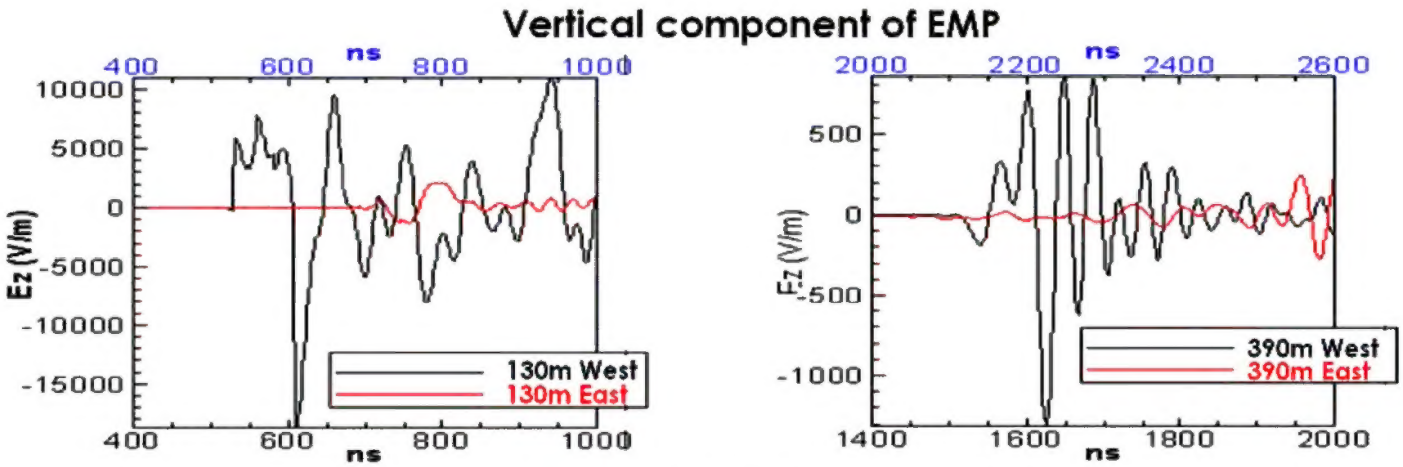
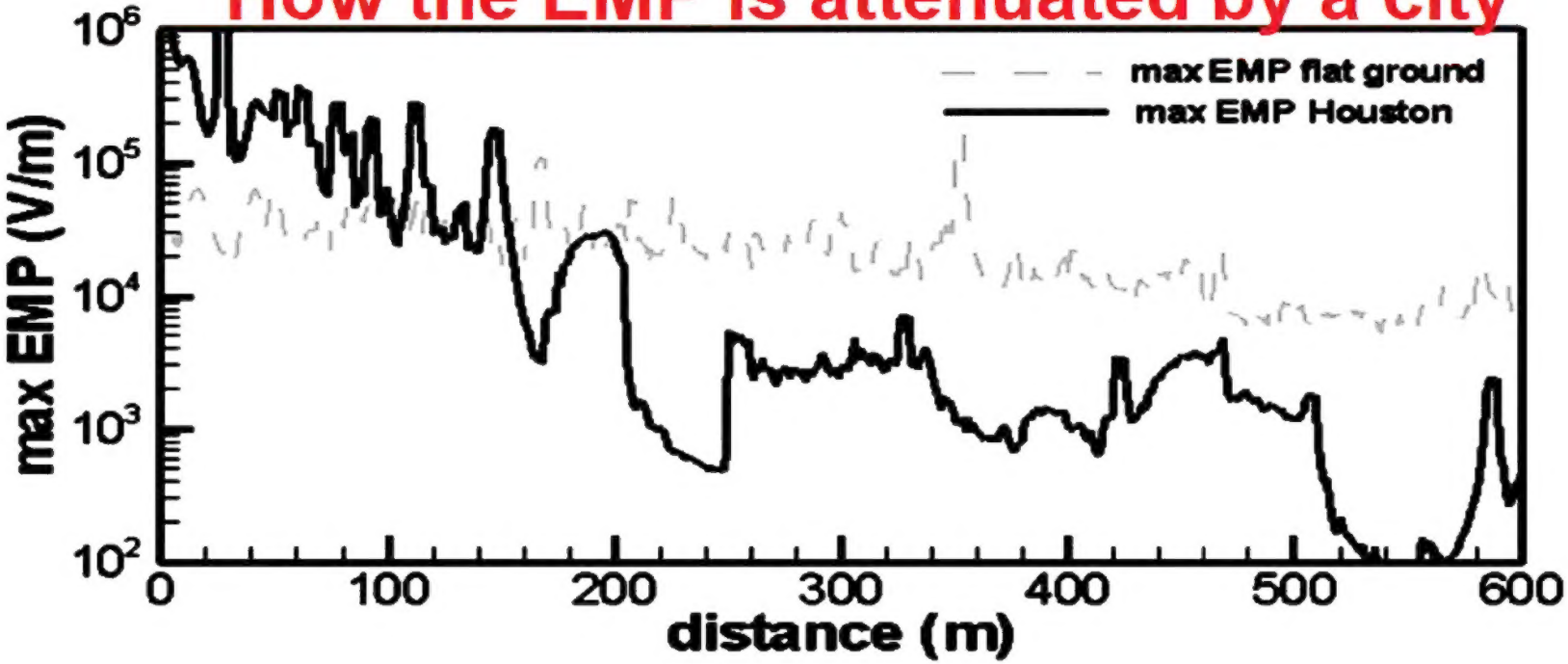


Figure 6 Plot of selected Castle data showing the relationship between peak field strength and yield on a north-south path. Probable curves, drawn by inspection, are shown for Pt. Barrow and Thule.



William S. Smith, et al., Nuclear EMP simulation for large-scale urban environments, Los Alamos, LA-UR-12-20227, 2012

How the EMP is attenuated by a city



Effects of buildings on maximum EMP from a generic "Fatman" type bomb in downtown Houston, Texas

Tall buildings (1) attenuate horizontal prompt gamma rays, (2) attenuate the line-of-sight (UHF) EMP frequencies

Scott Smith, Jeff Bull, Trevor Wilcox, Randy Bos, Xuan-Min Shao, Tim Goorley, Keeley Costigan
Nuclear EMP simulation for large-scale urban environments, Los Alamos LA-UR-12-24078, August 2012